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JOURNAL
OF THE
AMERICAN SOCIETY OF NAVAL ENGINEERS

VOL. 47. NOVEMBER 1935 No. 4

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ILLUMINATION ON NAVAL VESSELS.

By T. E. CASSEY, MEMBER.*

The first incandescent lighting installation in the U. S. Navy was installed on the U.S.S. *Trenton* in 1883. This installation consisted of seventy 16-candlepower lamps, one hundred seventy-three 10-candlepower lamps and four 32-candlepower lamps, a total of two hundred forty-seven lamps and 2978 candlepower. Power was supplied by a 110-volt dynamo rated at 120 amperes (13.2 Kw.). At that period (1883) the rated efficiency of incandescent lamps was comparatively low, being approximately 4.6 watts per candlepower, which gave the plant on the U.S.S. *Trenton* a capacity of slightly less than 2900 candlepower.

The lamps were fitted in ceiling fixtures, bulkhead standing lights, electroliers and bracket fixtures much the same as in present installations. Portables were provided and lamps installed in the

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running and anchor light fixtures. The voltage of lamps in this plant was regulated by the eye, and was adjusted to give less candle-power than the lamp ratings to prolong the life of the lamps. Apparently the operation of the lamps at the low efficiency thus obtained was not considered objectionable, as the installation even as operated, was much superior to the oil lamps with which vessels were fitted in those days. It would be interesting to know what illumination intensities were obtained on the *Trenton* with this installation.

From this initial installation on the *Trenton,* the lighting system on the naval vessel has grown, keeping pace with the demands of naval construction, until we have on the modern 10,000-ton cruiser a lighting system approaching 2400 units, exclusive of special lights for signalling and indicator service and other illuminated devices. This quantity of units is divided approximately into the following groups: 1500 50-watt general illumination units; 200 100-watt and 200-watt general lighting units; 250 50-watt desk and berth fixtures; 250 25-watt standing lights and lanterns and 200 50-watt portable fixtures; a total of approximately 134 kilowatts. With this expenditure of power it should be possible to develop an adequate return in the way of an efficient illumination system.

Prior to the recent preparation of the electric plant specifications for new naval vessels, illumination systems were developed under what may be termed a " type plan " method or procedure. Under this procedure the number and type of lighting units were " spotted " on deck arrangement plans, these plans forming a part of the vessels' contract plans. The quantities, locations and wattage of lighting units provided for the various ship compartments, on these plans, were determined largely on the basis of past practice. In undertaking the development and installation of the lighting system the shipbuilding contractor, not being responsible for the wattage within the compartments, followed the type plan arrangements rigidly, with the result that the lighting units were usually installed with a view to obtaining a symmetrical ship layout rather than providing illumination suitable for carrying on the necessary ship activities within the compartments.

During the construction of naval vessels numerous structural changes occur and much rearrangement of furniture and other

compartmental fittings is occasioned, with the result that locations of lighting units made in accordance with "type plan" arrangements are in many instances not in accord with the final compartmentation of the vessels. The revamping of the lighting system to conform to these changes is always a controversial matter. In addition to the difficulties experienced with compartmental changes, difficulties were also encountered in locating lighting units in accordance with type plan arrangements, due to overhead hamper such as ventilation ducts, pipes, mess tables, etc. Many lighting units on present ships are rendered inefficient by these overhead obstructions.

Under the system of developing and installing the lighting system as described above, it could not be expected that any uniformity in illumination intensities would be obtained. It has long been recognized that illumination intensities varied greatly not only for compartments of like service on different vessels, but between like compartments on the same vessel, also that the illumination differences, within the confines of the larger compartment was excessive. Some attempts have been made in the past to measure illumination on naval vessels and to standardize intensities for the compartments but no definite steps were taken until the preparation of the electric plant specifications for vessels of the 1933 building program.

Toward the end of the year 1932 it was decided to conduct illumination surveys on two newly constructed vessels for the purpose of determining what illumination intensities were actually obtained with the system of lighting as then installed, and also to determine what intensities were required for compartments for naval vessels. The U.S.S. *Portland* (CA33) and the U.S.S. *Indianapolis* (CA35) were selected for obtaining this data.

An illumination survey was conducted on the U.S.S. *Indianapolis* in December, 1932, and a like survey on the U.S.S. *Portland* in February, 1933.

In these surveys, which were conducted by the writer, in company with commercial illumination engineers, illumination intensities were measured in representative compartments on the two vessels, using a Weston photo-electric cell type of foot candle meter. In compartments containing machinery, tables, desks, workbenches, etc., readings were taken at the working level of such installations. In open spaces such as crew's quarters where there were no installa-

tions of this character, readings were taken on a horizontal plane 30 inches above the deck. Voltage readings were taken and recorded for the majority of the compartments, a bus voltage of 120 volts being maintained as nearly as practicable at the main switchboards. On the U.S.S. *Indianapolis* illumination intensities were measured in 85 compartments; over 700 readings being taken and recorded. On the U.S.S. *Portland* illumination intensities were measured in 115 compartments; over 900 readings being taken and recorded.

Data were taken and tabulated as follows for each compartment surveyed:

1. Foot candles; maximum, minimum, average.
2. Spacing of lighting units.
3. Watts of lighting units.
4. Type of reflector.
5. Ceiling height.
6. Mounting height.
7. Working height.
8. Color of compartment.
9. Voltage.

As the writer has been questioned at times as to the procedure used in these surveys, it may be of interest to set forth the few simple rules followed. The compartment to be surveyed was first given a general appraisal to settle its classification as to illumination as determined by the ship activities carried on therein. Then the type of units used was appraised with a view to their proper selection and location for the duty concerned. Checking the wattage of the lamps installed, and relamping as necessary, measuring the voltage and then excluding any daylight were the next steps, and were taken successively. Readings were then taken at the proper level and in positions carefully selected to establish the degree of illumination installed. Very interesting results were obtained in some compartments and some of these results are described later in this article.

Table I, following, shows the maximum, minimum and average foot candles for general illumination for typical compartments surveyed on the two vessels:

TABLE I.

Foot Candle Levels for General Illumination Obtained from Survey for Typical Compartments on the U.S.S. *Portland* and U.S.S. *Indianapolis*.

	Indianapolis.			*Portland.*		
	Max.	Min.	Av.	Max.	Min.	Av.
Armory	15	1.5	5	7	2.5	4
Cabin	3	2	2.5	9	3.5	5.8
Central Station	7	1	3.5	4	0.5	2.5
Chart House	4	1	2.75	1.5	0.5	1.2
Crew Space	6	1	2.5	5	0.5	2.4
Fireroom—Upper (Front of Boilers)	40	4	18	6	3	5
Fireroom—Lower (Front of Boilers)	5	1	3	3.5	2	2.5
Galley—Crew	9	1	3.7	4.5	1.5	3
Handling Room	2	1	1.5	1.5	1	1.3
Ice Machine Room	2	0.5	1.4	3	0.5	1.4
Laundry	3	1	1.75	8	2	4
Machinery Space—Upper	46	3	10	12	1.5	4.5
Magazines—8-inch Powder	1.75	1	1.5	2	1	1.7
Mess—Crew	4	0.5	1.5	4.5	1	2
Office—Engineers	10	2	5	4	1	2.8
Pantry—Wardroom	2	0.5	1	5	2.5	3.3
Plotting Room	9	2	5.1	10	3	6
Radio Room—Receiver	2	1	1.3	2	1.5	1.7
Shop—General Work	45	1	18	23	1	10.5
Stateroom Single	5	2	4.3	3.5	2	2.5
Steering Room	2	1	1.5	1.5	0.3	0.8
Stores—Bulk	2	1	1.25	2.5	0.8	1
Turret—Gun Chamber	2	1	1.25	2	1	1.4
Washroom—Crew	5	0.5	2.4	1.8	1	1.1

Examination of the comparative values for illumination in like compartments for the two vessels given in the foregoing Table I will show the variance existing in lighting installations for two modern vessels, although of the same class, and with the installations developed from the same contract plans.

Throughout the two vessels it was found that insufficient attention was paid to the detail illumination of gauges, thermometers, workbenches, mirrors, tables, desks, racks, bins, scuttles and it appeared to be the procedure to leave the illumination of these items to the scheme of general illumination. In many cases it was noted that lighting unit locations had apparently been selected on an expected arrangement of ship material and furniture which was later modified, resulting in the lighting unit locations being contrary to the final ship installation. It was also found that many lighting units were located so that illumination from these units was greatly blanked by piping, ventilation ducts, banks of cables, etc. This was particularly true of lighting units that would have served for detail illumination of individual gauges, thermometers, etc., if more suitably located. It was noted that the painting of the vessels' compartments and of the material within the compartments had a decided effect on the comparative illumination levels.

Some of the lighting arrangements found in representative compartments on the U.S.S. *Indianapolis* and U.S.S. *Portland* are described briefly to show more clearly the failure of the "contract plan" system to produce an efficient lighting system.

FIREROOMS.

It was found in the firerooms of both vessels that 200-watt watertight units were used for general illumination on the upper level and 50-watt watertight deck fixtures for the lower level. This unbalanced installation produced average illumination intensities on the upper level in front of boilers of 18 f.c. for the *Indianapolis* and 5 f.c. for the *Portland*. On the lower level the intensities were 3 f.c. for the *Indianapolis* and 2.5 f.c. for the *Portland*. Between boilers on the *Portland* the illumination intensity was 10 f.c. which is above that in front of boilers on this vessel. From these values it will be seen that the illumination was not uniform, an excessive brightness difference was present between upper and lower levels, and, as illustrated by the 10 f.c. between boilers, illumination was not placed to the best advantage to utilize the wattage expended. The illumination of guage board, gauges, workbench, log desk, etc., was found to be poor. One gauge board on the *Portland* was found to have only 1.5 f.c. and gauges were

found as low as 0.5 f.c. The log desk on both vessels showed 2 f.c. and the workbench was found with 0.75 f.c. All these illumination values are too low for satisfactory service. The illumination for gauge boards, gauges and the log desk should be provided by suitably located deck fixtures, having suitable reflectors or shields, and in this connection polished surfaces of gauge boards should be avoided to prevent glare. Water gauges should be illuminated by Bureau standard gauge lights.

MACHINERY SPACES.

In the main engine rooms of both vessels 200-watt watertight units were installed for upper level general illumination and 50-watt deck fixtures for lower level similar to fireroom installations. This installation produced average illumination intensities on the upper level of 10 f.c. for the *Indianapolis* and 5 f.c. for the *Portland*. The average illumination intensities for the lower level were 5 f.c. for the *Indianapolis* and 3.5 f.c. for the *Portland*. Detail illumination in these compartments, as in the case of firerooms, was entirely inadequate. Gauges were, in general, poorly illuminated, and numerous gauges on both vessels could not be read from a reasonable distance without the aid of flashlights. The main gauge boards on the *Indianapolis* were too brilliantly lighted, having an illumination intensity of 20 f.c., whereas the main gauge board on the *Portland* was low, with 4.8 f.c. The workbench on the *Indianapolis* had illumination of less than 0.5 f.c. while on the *Portland* the workbench illumination was 9 f.c. The log desk illumination on one vessel was 3 f.c. and on the other vessel 4.5 f.c. The air compressor installation on one vessel had no illumination and on the other vessel 4.5 f.c.

In evaporator rooms similar conditions were found as described for main engine rooms. In ice machinery rooms conditions were worse, as the light absorption in these spaces was extremely high, due to the machinery installation being of very dark color. The average intensities in these compartments, for both vessels, was less than 1.5 f.c. Gauges and thermometers had practically no illumination and in most cases could not be read without flashlights.

It is interesting to note that the personnel in these compartments were so accustomed to the use of flashlights in taking readings on

account of long service in poorly lighted compartments, that the lack of illumination for vital installations, which is so evident to the commercial engineer, was accepted as a matter of little consequence.

WORKSHOPS.

In workshops, on both vessels, 100-watt non-watertight units were installed for general illumination. Although the average intensities in these compartments were higher than in machinery compartments, the illumination was not entirely satisfactory in view of the fact that lighting units were not located so as to provide uniform intensity at the tools. In the general workshop, on one vessel, intensities varied from 30 f.c. on the shaper to 1 f.c. on the hacksaw. Workbench illumination was generally inadequate and intensities were not uniform, varying from 15 f.c. on general workshop benches, 8.5 f.c. on workbenches in shipfitter's shop and 3.7 f.c. in carpenter shop. Intensities also varied considerably on workbenches in the same shop. Lighting units in shops should be located with a proper understanding of the position of men operating machines and working at workbenches so that unobstructed lighting will be provided at the cutting part of the tool and so that shadows are not thrown by the operator on the stock being worked.

OFFICES.

The illumination in offices was entirely insufficient, probably more so than any other spaces surveyed. The following values will show the low intensities as found on these vessels:

Supply office	3.3 f.c.
Engineer's office	3 f.c.
Flag office	2.4 f.c.
First Lieutenant's office	4.5 f.c.
Captain's office	2.3 f.c.
Ex. Officer's office	3.4 f.c.

Ceiling fixtures installed in offices should be fitted with reflectors for intensifying the illumination at the working plane of the compartment and smoothing out the distribution, not possible with bare

lamp units. Indirect lighting would undoubtedly prove to be a better method of illumination for offices due to the nature of the work performed in these spaces.

Typewriter desks and flat top desks should be provided with individual desk fixtures. For large desks such as plan desk in the engineer's office, the flat top desk in the First Lieutenant's office, etc., one or more desk lights as required should be installed. Overhead lighting units should also be installed for these large desks. For the plan desk in the engineer's office, illumination should be provided for the plan drawer when in opened position. For desks in Admiral's and Captain's offices, 100-watt overhead units should be installed.

LIVING SPACES.

In the staterooms, on both vessels, 50-watt ceiling fixtures were installed for general illumination, one fixture being provided for single rooms and two fixtures for double rooms. The average illumination intensity in these compartments varied in different staterooms on the same vessel and also between the two vessels from a minimum of 2 f.c. to a maximum of 4.3 f.c., this variation resulting from the size and shape of the room, the effect of overhead interferences, etc.

Ceiling fixtures for staterooms should have translucent shades to reduce glare and should be installed in number and of such wattage as necessary to provide uniform illumination regardless of stateroom size. For the large staterooms, the Admiral, Captain, Executive Officer, etc., 100-watt units should be used in place of ceiling fixtures. Staterooms should always have detail lighting for the shaving mirror, secretary bureau and for the berth.

In cabins and in the wardroom on both vessels 100-watt hemisphere units were installed for general illumination, with bracket fixtures over transoms, producing average general illumination intensities in the wardroom of 4 f.c. on the *Indianapolis* and 6 f.c. on the *Portland*. In cabins the intensities were generally lower and varied from 6 f.c. in the Admiral's cabin to 1.7 f.c. in the Chief of Staff's cabin. Six f.c. is considered adequate for wardroom and cabins and no difficulty will be experienced in obtaining this inten-

sity with standard 100-watt ceiling units if the proper spacing of units is maintained.

In W.O. and C.P.O. messrooms 100-watt hemisphere fixtures were installed for general illumination, the average illumination intensities varying from 10 f.c. in the C.P.O. messroom to 5.7 f.c. in the W.O. messroom. In the case of the C.P.O. messroom on the *Indianapolis,* where the average of 10 f.c. was found, an increased number of 100-watt units was used in comparison with other spaces on the two vessels. The 10 f.c. level is not considered excessive from a lighting standpoint but it is not good practice to have one compartment of a group illuminated to a higher degree than other compartments of like character.

CREW SPACES.

On both vessels, 50-watt ceiling fixtures were installed in these spaces. The average general illumination intensity found on the *Indianapolis* was 2.5 f.c. and on the *Portland* the intensity was 2.1 f.c. On the *Indianapolis* ceiling fixtures were mounted directly on the overhead deck and on the *Portland* fixtures were mounted on brackets secured to the vertical face of deck beams so that the bare lamps were visible below the bottom of the deck beams. The installation of fixtures on the *Portland,* while producing more glare, resulted in less obstructions in the light from pipes, cable racks, vent ducts, etc. The use of reflectors on lighting units in crew spaces would improve the illumination by smoothing out the distribution, reducing glare and increasing the illumination intensity at the working plane of this compartment. These reflectors would undoubtedly raise the illumination intensity well above the 2.5 c.p. value without increase of wattage.

Mirrors in crew spaces had no illumination other than that received from the nearest ceiling fixtures, which fixtures were located with no particular reference to mirror illumination. At least one ceiling fixture should be located for illumination of each mirror, this fixture to have a suitable angle reflector (not a shield) for directing the illumination on the mirror.

Bulletin boards were illuminated by desk fixtures mounted on bulkheads directly above the top of the boards. These desk fixtures, so mounted, were so close to the vertical plane of the bulletin

boards that the resulting illumination is poor, the lower half of the bulletin boards receiving little illumination. Fixtures for illuminating bulletin boards should be located preferably on the overhead deck and about one-half the length of bulletin board away from the face of the boards so as to throw light on the entire front of the bulletin board.

In crew's spaces the tops of pea-coat lockers which are used as writing desks received no illumination other than that obtained from the nearest overhead ceiling fixture. The top of these lockers should be lighted either by a desk fixture or by an overhead ceiling fixture located so as not to cast shadows where a man is writing.

STORES AND ISSUING ROOMS.

On both vessels 50-watt ceiling fixtures (with guard) were installed for these compartments. In bulk storerooms the average intensity was found to be 0.75 f.c. and it was noted in many cases that fixtures were not installed with proper reference to the arrangement of stowage of material. A value of 1 f.c. will be sufficient for these compartments, with readings taken in aisle spaces.

In storerooms with bins the average illumination was slightly higher than bulk storerooms, being close to 1.5 f.c., which value is suitable for these spaces. Care should be taken to see that lighting units in these compartments are installed in aisle space between the rows of stowage racks.

The average illumination intensities found in issuing rooms on both vessels were extremely low, being 1.3 f.c. on the *Indianapolis* and 1 f.c. on the *Portland*. The minimum intensity considered suitable for general illumination in issuing rooms is 2.5 f.c., with 10 f.c. at the issuing desk.

Particular care should be taken in locating fixtures in issuing compartments to see that fixtures are in center of aisle spaces and not over bins. Fixtures were not well located in this respect on the *Indianapolis* and *Portland*. Bins being painted dark green absorbed an excessive amount of light. It is highly desirable that the color of these bins be changed to improve lighting conditions in these compartments.

PANTRIES AND SCULLERY.

In the pantries on both vessels 50-watt ceiling fixtures were installed for general illumination. The average illumination intensities found were low in some cases as indicated by the following:

Indianapolis.		*Portland.*	
C.P.O. Pantry	3 f.c.	C.P.O. Pantry	2 f.c.
Wardroom Pantry	1 f.c.	Wardroom Pantry	3.3 f.c.
Captain's Pantry	2 f.c.	W.O. Pantry	2.8 f.c.

In most cases the sink in pantries had no illumination, and should have a fixture directly overhead. Dish washers also require an individual lighting unit.

In the scullery, like the pantries, the illumination intensity was low, being 1.3 f.c. on one vessel and 1.7 f.c. on the other vessel. No lighting was provided for the sink, the sterilizer or the washer trough. This was particularly noticeable in view of the particular function of this compartment being one of cleanliness.

TURRETS.

In the turrets, the illumination was insufficient for the performance of duties requiring the highest speed and accuracy of all spaces on the vessels. In gun chambers the intensity was 1.25 f.c. on both the vessels; on the electrical platform 1 f.c. was found, in the powder handling room and shell handling room less than 1.5 f.c. and the trainers and turret officers' booths the same conditions. These levels should be increased materially.

From the data obtained from surveys on the U.S.S. *Indianapolis* and *Portland*, a table of standard values for minimum average foot candles for the various ship compartments was determined. These standard illumination intensities have been incorporated in electric plant specifications for new naval vessels.

In this first listing of these values, foot candle intensities were specified, in some instances, in ½-foot candle steps. This was due to the adoption of minimum average intensities for some compartments as found on the two vessels, wherein the illumination seemed adequate for the performance of the ship activities. This procedure was followed to avoid large increases in the number of lighting

fixtures and serious changes in wiring systems, while placing standard lighting values in effect for initial installations.

For commercial work, the ½-foot candle steps are considered too close a graduation. The latest thought for commercial installations now indicates the tendency to increase lighting values in multiples of the basic values; for example, if an intensity of 2 foot candles is inadequate, the next step of increased lighting would be 4 foot candles; likewise, the increase over 10 foot candles would be to 20 foot candles, etc. These ½-foot candle steps have now been eliminated for later construction.

With bare acid etched lamps as specified at that time for standard ceiling fixtures, the light distribution is such that the foot candle level is greater beneath the lamp than the general average around the compartment. The standard levels determined, therefore, were based upon the assumption that the lighting units would be placed with reference to the important points of the particular compartment and so that the intensities at these points would be higher than the general average.

It is realized that these standards for illumination intensities being determined on the basis of heavy cruiser installations, may not in all cases be applicable to all classes of vessels such as destroyers, submarines and airplane carriers. The addition of other values applicable to particular classes of vessels will undoubtedly be necessary to suit the individual requirements of such vessels. Table II gives standard illumination values for representative ship compartments as first determined.

While recording the general illumination data in the various compartments and spaces for the U.S.S. *Indianapolis* and *Portland*, readings were taken on such items as bulletin boards, desks, gauges, gauge boards, mirrors, sinks, tables, transoms, workbenches, etc., where intensities should be higher than the average general illumination. Table III shows foot candle readings recorded for this detail lighting and it is surprising to note the inadequate illumination provided.

TABLE II.

List of Minimum Average Foot Candle Levels for Typical Compartments and Spaces on Naval Vessels.

Compartment.	*Min. Average Foot Candles.*
Cold Storage Space Drying Room (uptake) Stores—Bulk	1
Blower Room Magazines Shaft Alley Stores—Bins Turret or Mount—Handling Room	1.5
Airlock Bath Handling Room Passage	2
Crew Space Issuing Room Radio Room Windlass Room	2.5
Bakery Chart House Galley and Pantry Fireroom, Lower—Front of Boilers Ice Machine Room Messroom—Crew Quarters, C.P.O. Radio—Communication Station Pump Room Stateroom Turret or Mount—Gun Chamber	3

Compartment.	*Min. Average Foot Candles.*
Central Station Distribution Room	4
Armory Dispensary Evaporator Room—Upper Generator Room Machinery Space Office Shop—Cobbler and Tailor Steering Motor Room	5
Cabin Messroom	6
Hangar Shop—Coppersmith Shop—Sheet Metal Shop—Shipfitter	8
Laundry Shop—Carpenter Shop—Electric Shop—General Work	10
Plotting Room Shop—Printing	15

TABLE III.

Foot Candle Levels Obtained from Surveys for Detail Lighting on the U.S.S. *Indianapolis* and U.S.S. *Portland*.

Item.	*Indianapolis.*	*Portland.*
Bulletin Boards	....	4
Desk, Log—Machinery Space	3	3
Desk, Log—Boiler Room	2	2.2
Desk, Log—Ice Machine Room	1	1
Desk, Plan—Engr. Office	6	3.3
Gauge Board, Main—Aft. Mach. Space	20	4.5
Gauge Board, Fireroom No. 1	5	1.5
Gauges, Evaporator Room	1.9	4
Mirror, Washroom—C.P.O.	0.5	1.2
Sink, Galley—Crew	3	3.5
Table, Messroom—Wardroom	4	8
Table, Bakery	3.5	2.25
Table, Chart—Chart House	10	10
Transom, Messroom—Wardroom	4	3.5
Workbench, Machinery Space F	1	9
Workbench, General Workshop	15	....
Workbench, Armory	8.5	10
Workbench, I. C. Room	8.3	3.8

After consideration of the illumination values contained in the foregoing table and the recommendations of the two companies assisting in this project, Table IV, following, was developed, containing illumination values for detail lighting. These values have been incorporated in the electric plant specifications for new vessels and their adoption will result in great improvement in the illumination of detailed equipment in vessels' compartments.

TABLE IV.

Foot Candle Levels for Detail Lighting on Naval Vessels.

Item.	*Min. Average Foot Candles.*
Berth (Reading)	7
Bulletin Board	5
Desk—Log	5
Desk—Typewriter and Flat Top	15
Gauge Board and Gauge	10
Mirror	10
Radio Receiver Table	15
Sink	5
Switchboard—Main (Vertical)	8
Table—Messroom and Cabin	6
Table—Chart	15
Table—Tracking	20
Table—Bakery, Galley, Laundry, etc.	5
Thermometers	5
Transom (Reading)	6
Workbench—General Workshop, Electrical Shop, Armory, Torpedo	15
Workbench—Carpenter Shop, Shipfitter's Shop	10
Workbench—Machinery Space, Fireroom, Evaporator Room, Hangar, I. C. Room, Gyro Compass Room, Battery Charging Station	6

The question is sometimes asked why industrial illumination values cannot be used on naval vessels and, further, why industrial lighting units are not suitable for naval installations. These ques-

tions may be answered by merely pointing to the fact that all installations on naval vessels differ from commercial installations as required to suit the necessities of the naval service. The particular reasons why industrial lighting units are not suitable for installation on naval vessels are the lack of deck height or head room, the irregular shape of compartments, the multiplicity of overhead obstructions and the potential danger to units from shock of gunfire. These reasons lead to the use of many low wattage units spaced closely and a very limited use of diffusing glassware, whereas the commercial lighting installation, with high ceiling height leans toward the use of larger and fewer units,—a more efficient installation.

The trend in industrial illumination is one of increased values. More and more illumination is being demanded for increased attractiveness, for advertising value and for greater efficiency in manufacture, etc. The illumination on naval vessels must necessarily be maintained at a lower level than industrial applications, for reasons of economy, lack of space and military necessity. Table V following shows a comparison of the newly adopted Navy Illumination values with industrial values for representative ship compartments:

TABLE V.

Foot Candle Levels for Industrial and Naval Applications.

	Industrial.	*Navy.*
Bakery	20	3
Barber Shop	20	5
Bath	5	2
Butcher Shop	10	3
Cabin	12	6
Galley (Kitchen)	10	3
Ice Machine Room	10	3
Machinery Space	10	5
Living Space—Crew	10	3
Messroom—Wardroom	10	6
Office—General	20	5
Stateroom	10	3
Shop—Carpenter or Machine	20	10
Washroom	5	3

In 1927 when the inside frosted "A" lamps were adopted for naval vessels, it was thought that due to the extreme reduction in the transmitted brilliancy of the filament and the great reduction in glare of these lamps, as compared with clear lamps then used, that diffusing glassware could be dispensed with. As the use of glassware for lighting fixtures was always found to be a source of trouble on shipboard due to breakage under shock of gunfire, the opportunity to eliminate this source of trouble was eagerly grasped and diffusing glassware was removed for all lighting units except where the watertight integrity of these units was necessary.

The installation of the bare inside frosted "A" lamps on naval vessels without either diffusing or reflecting mediums has not proven entirely satisfactory in certain locations, notably in living quarters, offices, medical spaces, barber shop, etc., for the following reasons:

(*a*) Bare lamps produce glare which is particularly objectionable where installed at or near the eye level.

(*b*) Bare lamps in overhead installations produce an uneven light distribution and cause deep shadows particularly noticeable in offices.

(*c*) With bare lamps the illumination is "spilled" in all directions and is not directed so as to provide the maximum illumination in the direction where it is needed.

In industrial installations, experience has proved that correct lighting is a vital factor in creating efficiency. Properly distributed light assures accurate vision over the entire field of operation and permits all details to be easily discerned. Direct or reflected glare causes eye strain resulting in general fatigue and carelessness. Shadows produced from glare prevent quick vision, thereby prolonging the time necessary for any operation. If correct lighting is found essential in industrial applications for the reasons enumerated, then doubly so is it necessary on the naval vessels where speed and accuracy are of even greater importance than in the field of commercial industry.

The adoption of standard foot candle values for compartments on vessels leads to the question of the proper determination of the number and wattage of lighting units to be installed to fulfill these requirements. In this connection it is equally important for the designer to guard against the installation of an excessive number

of units as it is an insufficient installation. In complying with Table II, the tendency undoubtedly will be to play safe and install units to a maximum quantity rather than risk the necessity of revamping the installation to provide for deficiencies.

In the calculation of illumination systems for industrial interiors the designer is concerned with the following four steps or factors, values for which must be determined in the order listed:

1. Foot candles required.
2. Type of lighting units.
3. Location of lighting units.
4. Lamp size.

As lighting installations on naval vessels have not been "calculated" in the past, the adoption of this commercial procedure to naval installations will prove interesting. For the purposes of illustration, we will take a representative compartment on board ship such as the wardroom, and follow through the calculations for determining the proper illumination installation. Referring first to Table II, we find the illumination intensity for the wardroom given as 6 f.c., which satisfies Step No. 1. The next step is to determine the "Type of Lighting Units." In the commercial world with the large number of types of lighting units available the selection of the proper lighting units involves the following seven factors:

(*a*) Relative foot candles for lamp size on horizontal.
(*b*) Relative foot candles for lamp size on vertical.
(*c*) Appearance of lighted room.
(*d*) Direct glare.
(*e*) Reflected glare.
(*f*) Shadows.
(*g*) Maintenance.

For the naval installation the selection is narrowed down to the Navy standard lighting fixtures available and the ceiling unit, Type XIII, Bureau Engineering drawing 9-S-4545-L is chosen as best suited to satisfy the above seven factors.

Step No. 3 concerns the "Location of Lighting Units." Again referring to commercial practice we find the following two factors involved, *viz.*, mounting height and spacing. The following general rules give the proper determination of these factors:

1. Spacing of units should not exceed one and one-half times the mounting height above the working plane, and preferably, should be less.

2. Distance to side wall should not exceed one-half the spacing distance.

3. The spacing in one direction should not exceed one and one-half times the spacing in the other direction. Equal spacing in both directions is preferable.

4. Units should not be located in line with columns or stanchions.

5. The height of units determines the distribution or spread of the illumination, units, therefore, should be mounted as high as practicable.

Assuming the height of the wardroom to be 8 feet, and the "working plane" to be 3 feet, the maximum permissible spacing of units would be 7½ feet, with a wardroom size 24 feet square, and satisfying conditions 1 and 2 above, we would then have in the compartment 16 units spaced 6 feet on centers with a 3-foot distance from side walls.

The fourth step to determine is the "Lamp Size." In order to specify the lamp size necessary to provide the foot candles desired, the percentage of light emitted by the lamp that actually arrives at the working plane must first be determined. This percentage is termed the "Coefficient of Utilization." Assuming the efficiency of the lamp installed in lighting unit to be 100 per cent, the following figures will show how the losses in the transmitting of the light from the unit to the working plane are distributed:

Lamp efficiency	100%
Depreciation in lamp efficiency during life and due to collection of dust or dirt, 75 per cent	75%
Efficiency of the lighting unit (including reflector or globe), 75 per cent	57%
Utilization of the light (absorption by walls, etc.), 50 per cent	29%

From the foregoing it will be seen that less than 30 per cent of the lumens developed by the lamp are delivered for use at the work level.

Interior finish and room proportions have an important influence on illumination efficiency. In general, large rooms use light more

efficiently than small rooms as the larger rooms have less wall area in proportion to floor space, and consequently less absorption area. The proportion of rooms also has a bearing on illumination results as it can be readily seen that a long narrow room with high ceiling would be more difficult to illuminate than a perfectly square room with a height equal to its length and width. This classification of a room according to its proportions is termed " Room Index." To illustrate, the room index of a room 10 feet square and 10 feet high is 1 whereas the room index of this room if the ceiling height were doubled would be 0.6. The effect of room index on illumination efficiency will be seen by comparing the coefficient of utilization of 0.31 for a room having a room index of 1 with the coefficient of utilization of 0.22 for a room having a room index of 0.6, other variables remaining constant.

All the information necessary for the calculation of lamp size for the wardroom now being available from Steps 1, 2 and 3, we will apply the following formulae:

$$\text{(A) Area in Square Feet per outlet} = \frac{\text{Total Floor Area in Square Feet}}{\text{Number of Units}}$$

$$\text{Area in Square Feet} = \frac{24 \times 24}{16} = 36$$

$$\text{(B) Lamp Lumens per Square Foot} = \frac{\text{Foot Candles}}{\text{Coefficient of Utilization} \times \text{Probable Average Illumination in Per Cent of Initial Illumination}}$$

The foot candles for this formula, as already stated, is 6. The coefficient of utilization applicable to the wardroom installation taken from a table of Industrial Coefficients for a Room Index, of 1.5, based on a " very light " ceiling and " fairly light " walls, is found to be 0.38. The " probable average illumination in per cent of initial illumination " will be assumed as 0.70, representing average conditions. With these values now applied to formula (B) we now have:

$$\text{Lamp Lumens Per Square Foot} = \frac{6}{0.38 \times 0.70} = 22.6$$

$$\text{(C) Lamp Lumens per outlet} = \text{Area Square Feet per outlet from (A)} \times \text{Lamp Lumens per Sq. Ft. from (B)}$$

Lamp Lumens per outlet = 36 × 22.6 = 813.6

Having determined that 813.6 lumens is required per outlet from formulas (A), (B) and (C), the size lamp is found by reference to a table of "Lumen Outputs" of Multiple Mazda Lamps. In this table the value of 813.6 lumens falls closest to the lumen output of the 100-watt lamp. Therefore as a conclusion, the wardroom 24 feet square and 8 feet high would require 16 standard ceiling units, spaced 6 feet on centers to develop an illumination intensity at the working plane of 6 foot candles.

For use in calculating lighting for compartments on naval vessels, it will be necessary to develop tables of Coefficients of Utilization and room efficiencies applicable to naval installations.

Lighting units used on the majority of naval vessels, now in commission, are of Navy standard types, developed to suit the requirements of the naval service years ago. These units, where installed in "water-tight" compartments are of watertight construction and are fitted with diffusing globes. For non-watertight installations, with the exception of officers' messrooms and the Admiral's and Captain's quarters, lighting units are "bare lamp" fixtures.

These types of lighting units, which are indicative of those installed on the U.S.S. *Indianapolis* and *Portland*, for general illumination, are illustrated by Figures 1 to 6, following.

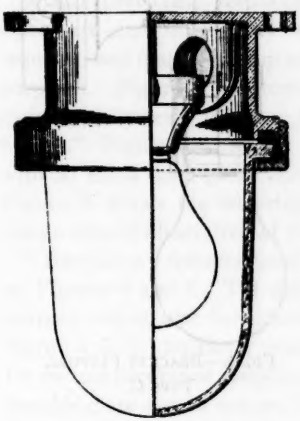

FIG. 1.—DECK FIXTURE, TYPE J.

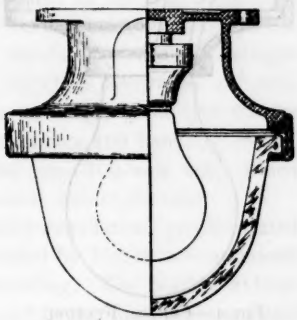

FIG. 2.—MAGAZINE FIXTURE, TYPE J.

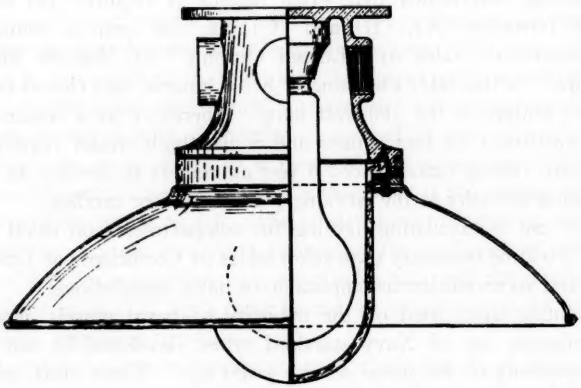

FIG. 3.—100-WATT UNIT, TYPE II.

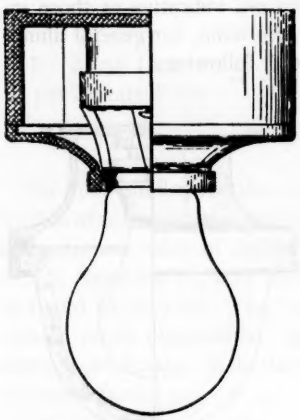

FIG. 4.—CEILING FIXTURE, TYPE VIII.

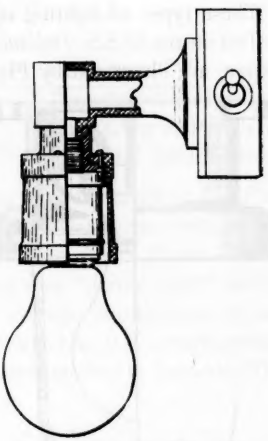

FIG. 5.—BRACKET FIXTURE, TYPE G.

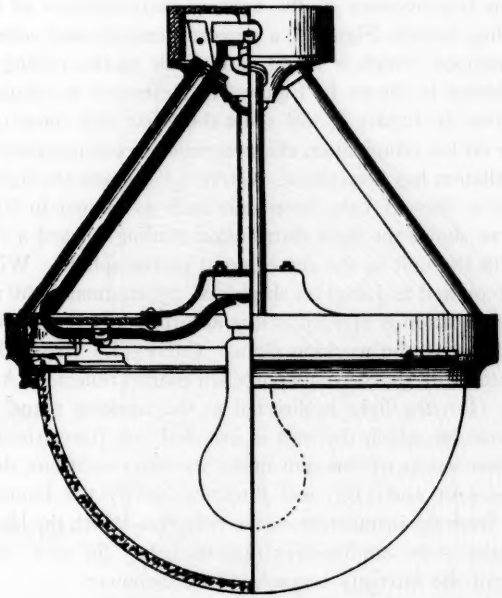

FIG. 6.—HEMISPHERE FIXTURE, TYPE II.

It was previously mentioned in this discussion that diffusing globes are used only where watertightness of lighting fixtures is required, and that bare lamp units are used for general illumination purposes. Figure 1 illustrates the standard 50-watt, watertight globe type, general purpose, fixture which is known as a "deck fixture." Figure 2 shows the 50-watt watertight globe type fixture with an extra thick globe used in magazines and handling rooms. Figure 3 shows the watertight globe type 100-watt unit, which design also is illustrative of the 200-watt watertight unit.

"Bare lamp" fixtures, used in present installations are illustrated by Figures 4 and 5. The unit illustrated by Figure 4 is a general purpose ceiling unit for overhead mounting. The bracket fixture, Figure 5, is for bulkhead mounting, and is used over transoms and for certain decorative purposes. Both of these units produce objectionable glare and an uneven distribution.

For the improvement of the lighting characteristics of the bare lamp ceiling fixture, Figure 4, a porcelain enamel steel reflector has been developed, which is readily attachable to this ceiling fixture. This reflector is shown in Figure 7. Reference to characteristic curves given in Figure 8, will show the effect that these reflectors will have on the illumination characteristics in compartments where this installation has been made. Curve (A) shows the light distribution of a 50-watt bare lamp unit such as shown in Figure 4. This curve shows the light distribution tending toward a spherical shape with the unit as the center point of the sphere. With these fixtures mounted as found on shipboard, approximately 50 per cent of the illumination is upward and is absorbed by overhead obstructions and lost to the working plane. Curve (B) shows the same fixture fitted with the 8½-inch porcelain enamel reflector. As shown by curve (B), the light is directed to the working plane, serving the purpose for which the unit is installed. A comparison of the candlepower values of this unit under the two conditions, described by curves (A) and (B), will illustrate clearly the improvement resulting from the installation of the reflector. With the bare lamp, the intensity is 30 candlepower directly below the unit, and with the reflector the intensity becomes 93 candlepower.

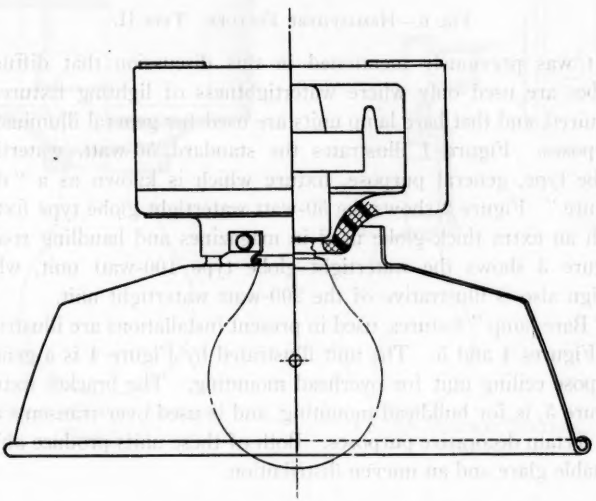

FIG. 7.—CEILING FIXTURE, TYPE VIII, WITH REFLECTOR.

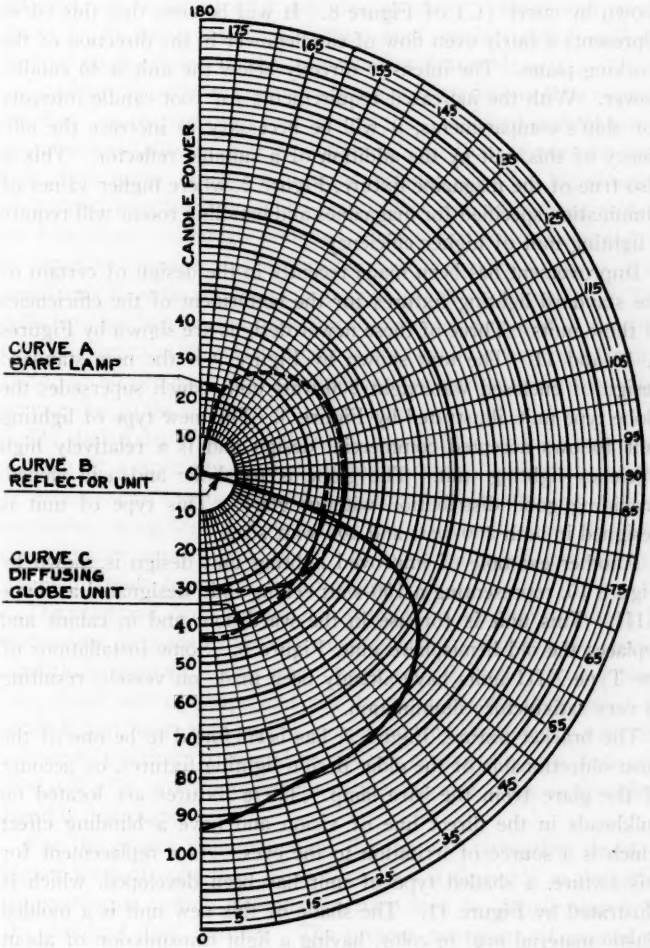
CANDLE POWER
CURVE A
BARE LAMP
CURVE B
REFLECTOR UNIT
CURVE C
DIFFUSING
GLOBE UNIT
180
175
165
155
145
135
125
115
105
95
90
85
75
65
55
45
35
25
15
5
0
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100

FIG. 8.

The characteristic curve of the 50-watt watertight deck fixture with diffusing globe, Figure 1, used for watertight installations is shown by curve (C) of Figure 8. It will be seen that this curve represents a fairly even flow of candlepower in the direction of the working plane. The intensity directly below the unit is 44 candlepower. With the increased requirements for foot candle intensity for ship's compartments, it will be necessary to increase the efficiency of this unit by the addition of a suitable reflector. This is also true of the magazine fixture, Figure 2, where higher values of illumination specified for magazines and handling rooms will require a lighting unit of higher efficiency.

Improvement has been made recently in the design of certain of the standard lighting fixtures for the betterment of the efficiencies of these units. Three of these newer designs are shown by Figures 9, 10 and 11. The unit shown by Figure 9 is the new standard design of enclosed watertight 200-watt unit, which supersedes the globe type unit, illustrated by Figure 3. This new type of lighting unit follows accepted commercial design and is a relatively high efficiency lighting unit. The globe is parabolic and acid etched, providing good distribution without glare. This type of unit is designed in both 200-watt and 100-watt sizes.

Another example of improved lighting unit design is shown by Figure 10, representing a 150-watt ceiling unit, designated as Type XIII. This unit is for use in the wardroom and in cabins and replaces the old hemisphere unit, Figure 6. Some installations of the Type XIII units have already been made on vessels, resulting in very satisfactory illumination.

The bracket fixture, Figure 5, has been found to be one of the most objectionable of the older design lighting fixtures, on account of the glare from the bare lamp. These fixtures are located on bulkheads in the direct line of vision and have a blinding effect which is a source of irritation to the eyes. As a replacement for this fixture, a shaded type of unit has been developed, which is illustrated by Figure 11. The shade of this new unit is a molded plastic material opal in color, having a light transmission of about 35 per cent. The new design of bracket fixture, in addition to its use over transoms, dressers, etc., will be also used as a berth light in place of the old metal shade type of berth light used for many

years. The opaque shade berth light restricts its illumination output to reading matter to an extent that results in too great a contrast between the reading matter and surroundings. There can be no doubt as to the greater satisfaction and comfort which will be derived from the use of this new bracket fixture design.

Considerable adverse comment is heard from time to time regarding that " many purpose " unit termed the " standard desk fixture," commonly installed in secretary-bureaus, over shaving mirrors, over typewriter desks and flat top desks and also used for illumination of bulletin boards, radio tables, etc. This fixture is fitted with a 50-watt lamp. Although designed for the first use enumerated,—in secretary-bureaus, this fixture has been extended to these other installations, with results perhaps not the best obtainable. The reflecting surface of the desk fixture as now designed is finished with aluminum paint, which finish, when new, may have a reflecting factor of 60 per cent; this factor being reduced considerably after service due to the darkening of the paint.

The desk fixture has recently been modified to provide a reflecting surface of a specially treated aluminum sheet having a specular reflection factor approaching 80 per cent, and this reflecting surface, moreover, being highly resistant to corrosion will retain this efficiency under service conditions. A much more efficient lighting unit will result from this modification.

The standard desk fixture, as installed in secretary-bureaus in staterooms, is probably the best obtainable for satisfying the service conditions required. This unit " being on the battle circuit " must be a fixed unit of shape and size to fit inside the desk, must be shaded, and must also permit closing of the desk cover with the fixture in position. It would be difficult to conceive of a desk unit that will offer any improvement in the characteristics as described for this desk light.

For the proper illumination of flat-top and typewriter desks, a higher level of light than heretofore used is desirable in the office compartments, which illumination may then be supplemented by the standard desk fixtures. The present procedure of depending upon the desk light for the greater part of this illumination of the desks produces poor " seeing " conditions.

For shaving mirrors the standard desk light will serve. For this service these fixtures should be mounted a sufficient distance from

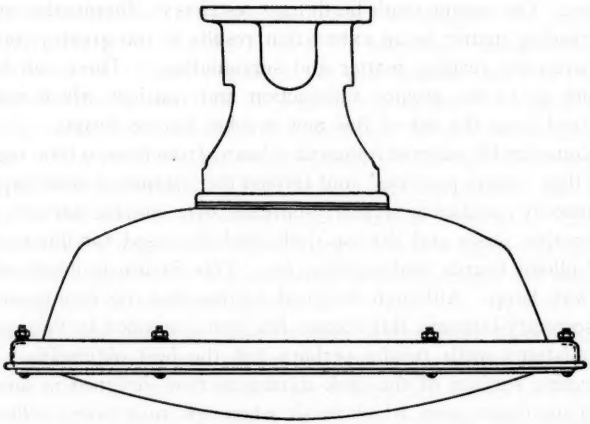

FIG. 9.—200-WATT UNIT, TYPE XII.

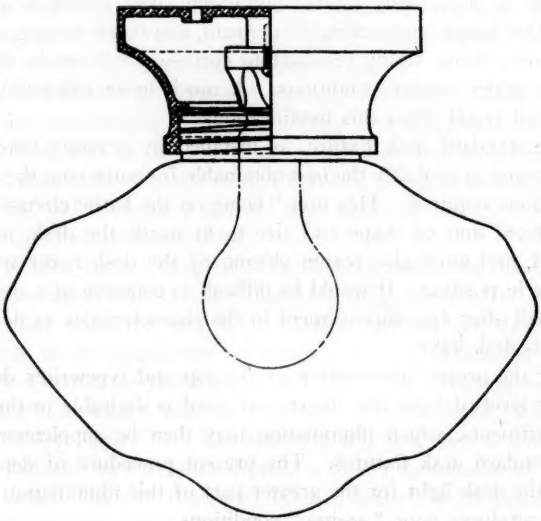

FIG. 10.—CEILING UNIT, TYPE XIII.

the face of the lighted plane to produce the illumination desired. A distance of 7 inches has been found to result in good lighting on the face. For bulletin boards a new unit has been developed such that the illumination will be distributed over the entire surface of the bulletins, not possible with desk lights previously used for this service.

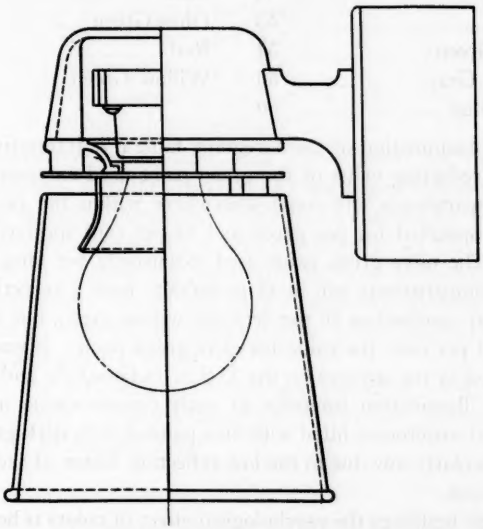

FIG. 11.—BRACKET AND BERTH FIXTURE, TYPE H.

Effective illumination for ship compartments, as is the case of industrial interiors, depends not only on the primary source of light, but also on the diffusion and reflection created in the compartment. The proportion of light reflected by the walls and ceilings in the various compartments, that is, the reflection factor of the finish of the compartment and other structures within the compartment, has therefore an important bearing on the illumination intensity. It is essential that the finish paint of the vessel's compartments be selected with a view to this finish being an aid to illumination so far as is compatible with the service activities performed within the vessel's spaces. The following table gives approximately the reflecting values of color in paint:

REFLECTION VALUES OF PAINT.

	Percent.		*Percent.*
Ivory	81	Straw	51
Canary	72	Light Lead	42
Cream	66	Pea Green	39
Buff	56	Blue	39
Pink	55	Olive Green	21
Pale Green	54	Red	20
Silver Gray	50	Willow Green	10
Sky Blue	50		

From examination of the foregoing table it is interesting to note that the reflecting value of the green paint used extensively in the ship compartments will come somewhere within the range of 39 per cent specified for pea green and 54 per cent specified for pale green. The olive green paint used extensively for bins, shelving, etc., in compartments will in all probability have a reflection factor above that specified as 10 per cent for willow green, but would not exceed 21 per cent, the value for olive green paint. It was particularly noted in the surveys on the U.S.S. *Indianapolis* and *Portland* that the illumination intensity in such compartments as issuing rooms and storerooms fitted with bins painted with dark green paint was particularly low due to the low reflection factor of the predominating paint.

In public buildings the psychological effect of colors is being given much importance. For naval vessels this factor is worthy of consideration.

The blue-greens and greens are cooling and cheering and become warming as they are varied toward the yellows. Browns are warming and to some extent subduing. The oranges and reds are stimulating; grays are usually to be avoided because they are not sufficiently colorful.

Since the preparation of the subject matter of this article an illumination survey has been conducted on a recently commissioned vessel. Although the specifications for lighting did not call for illumination in terms of foot candle values, as given in the foregoing Table II, the influence of this new procedure is found in this vessel's lighting system. The survey showed the contractor had

given the matter of proper illumination his close attention and much improvement was noted in the location of the lighting units. Illumination levels were generally well above those tabulated in Table I. Among the recommendations submitted by the engineers, who conducted this recent survey, are suggested increases in the foot candle values listed in Table II as follows:

That 1 and 1.5 f.c. values be increased to 2 f.c.
That 2.5 f.c. values be increased to 3 f.c.
That 4 f.c. values be increased to 5 f.c.
That 6, 7 and 8 f.c. values be increased to 10 f.c.
That 15 f.c. values be increased to 20 f.c.

These recommendations have since been adopted, and in addition to these changes, a further revision of these newer values has lately been made whereby illumination levels of 3 f.c. and 5 f.c. in the case of certain compartments, have been increased to 10 f.c. With the application of illumination intensities as now proposed, to new naval construction, vessels will have illumination systems that will be comparable with the intensities thought to be essential to proper vision in the industrial world.

NOTE: The following reference was consulted in writing this article: Electric Lighting Plan of U.S.S. *Trenton,* JOURNAL of the A. S. N. E. of August, 1920.

SUGGESTED IMPROVEMENTS IN PURCHASE REQUIREMENTS FOR IMPORTANT STEEL CASTINGS.

By LIEUTENANT CHARLES W. BRIGGS, U. S. N. R., MEMBER.

A considerable number of large steel castings are produced for Navy ships by the steel industry. The importance of some of these castings, such as turbine casings, high pressure steam castings and principal hull castings, to the military effectiveness and safety of the ships makes it imperative that their soundness be assured. It is often a difficult and costly job to attain the degree of soundness that is required. This is true because of certain inherent properties which are peculiar to the design of a casting or to its method of production. The soundness of a casting depends upon many things. Unfortunately it frequently depends on foundry technique. However, unsound castings resulting from poor foundry technique are inexcusable and, in general, will not be found extensively in the steel casting industry at the present time.

Unsoundness in Navy castings can often be traced to the fact that the organization which produced them was not properly equipped mechanically; the lack of proper heating equipment, sand processing machinery, handling devices, etc., resulted in the assembly of imperfect molds or the production of poor quality steel. To illustrate: The writer has observed the manufacture of a large casting by an organization which was from the beginning unable to produce a perfect casting because it did not have adequate furnace capacity. In order to make up for the lack of metal numerous large chills were placed within the mold. Even though the chills were practically of the same composition as the metal that was poured, the casting lacked the necessary homogeneity as was later found upon machining it.

The lack of proper equipment for making castings is not, however, as prominent a contributor to the unsoundness of steel castings as is the lack of the application of fundamental concepts. Basic

underlying facts as brought to light by research are few, and at present are somewhat academic in nature. Thus many factors that might aid in producing a sound casting are not known. For example, let us consider the fabrication of a large turbine casing. In the first place how is it to be designed? It is true that the designer knows what the stress and ductility requirements will be and he can plan the construction of the casting so as to take care of these, but he does not have any fundamental rules for guidance in the joining of sections of different thicknesses in order to insure soundness. Some steel casting producers offer a cooperative service to designers to facilitate a design that would be advantageous to both. These producers, apparently, have collected their knowledge of such design through long experience. The lack of publicly recorded data would lead one to conclude that perhaps the study of fundamental design problems has not generally progressed as far along the indicated lines as might be expected. The intelligent direction of design must be based on a fundamental knowledge of such factors as the method of solidification of the casting, the velocity of solidification, the rate at which the skin forms, and other items pertaining to the flow of heat about which very little information is available to the designer. A very absurd idea was expressed to the writer at one time by a foundry executive that the center of a 16-inch section was still in a molten condition five hours after it had been poured. Similar statements have been made from time to time by other foundrymen and lead one to believe that at present the necessary features of design from a foundry point of view should be handled only by a foundry organization which is awake to their importance and which has some definite plan of action. There are individuals and organizations that are very much concerned about good design and methods of controlling solidification. A case in point is the discussion of Direction Solidification and how it may be applied to steel castings, so ably presented in the pages of this JOURNAL by George Batty.

Under the term design may be grouped a number of subjects important in themselves but which in one manner or another modify or affect the design of a casting as a unit. With this in view a few of the more important physical characteristics may be pointed out to show the need for data which can be applied in the industry. In the contraction of a casting, how much restrained contraction

can be withstood before the metal gives way and external hot tears are formed; what are the conditions for long fluid life of steel in the running of a casting; in controlling the solidification of a casting by the use of chills, can the size of the chills be calculated to fulfill the exact needs, and if not what other methods can be followed? These problems and a host of others need solving before the soundness of castings can be definitely assured.

In the meantime, however, sound castings can be manufactured mainly through experience with pilot castings which will produce the necessary information leading to that end. Thus, at this time, experience with the actual production of a specific casting is the most important single factor contributing toward attaining a reasonably satisfactory result.

Let us now consider the application of the above considerations. Nearly everyone is familiar with the present system under which the Navy purchases steel castings. In general, a schedule is drawn specifying the requirements that are desired in a casting, the number of castings wanted, the delivery date, etc. The steel casting manufacturers of the country are then requested to bid on this schedule and the contract is awarded to the lowest bidder. Unfortunately, under the present system the government takes no cognizance of whether the low bidder has the necessary equipment to do the job, or whether he has ever poured an ounce of steel. Of course, practically, the circumstances are not always that bad, but several disappointing situations have arisen from time to time and prevail even today, though a considerable forward step in preventing them has been taken by the Navy Department in declaring in the steel casting specifications (49Sli) that "in general, the principal hull castings such as stem, sternpost, strut, and rudder castings shall be required to be subjected to radiographic examination."

Gamma ray radiography has done much to improve the soundness of these castings, for by this non-destructive method of testing important stress sections can be carefully checked for soundness in each casting prior to acceptance. It is usually not feasible, because of time and the heavy demand for available radium due to the extensive Navy building program, to radiograph an entire casting so there are always a considerable number of sections which must be overlooked in regard to internal soundness and must be judged only on surface conditions.

Since, as has been pointed out, it is necessary to rely on the ability and experience of the individual steel casting manufacturer to produce castings of satisfactory internal soundness, there is little if anything that the Navy can do by changing the scope of its present specifications which would help to promote internal soundness. The manufacturers, on the other hand, can do much to increase the internal homogeneity by producing one or more preliminary pilot castings of each design and examining them either by radiography or by cutting up at the locations where trouble is to be expected. If internal conditions are not satisfactory, certain changes should be made and another pilot casting produced. In this manner competent and progressive foundries have acquired a knowledge of each design which helps them to produce castings of similar design with a high degree of soundness. Thus, it would seem that such organizations are the ones from which the Navy should purchase their castings.

The Navy, of course, does give these competent organizations the privilege of bidding on the schedules, but the chances are that one of these organizations will not be the low bidder for the simple reason that, knowing the difficulties that may be encountered with specialty castings such as the Navy requires most frequently, and because of the greater care that is necessary, they quote a higher yet more representative price, a price that would guarantee an excellent casting. It is quite probable that the low bidder has never made a high pressure specialty casting and therefore knows nothing of the difficulties that may arise, still to his organization must be entrusted the manufacture of some part of the most important structure or machinery plant of a Naval vessel. The Navy Department is itself not at fault for such a condition for after all it desires to obtain the best casting that can be had. The trouble, therefore, arises from the system of allowing the lowest bidder to fulfill the contract regardless of whether he has or has not the ability, experience, and equipment to produce a satisfactory casting. Of course, eventually, some sort of castings are finally accepted, usually after numerous rejections. In such cases both the government and the contractor suffer, the former because of questionable castings, but primarily due to delays in production schedule on vessels building, and the latter through financial loss, often very heavy before the contract is complete.

It would seem that this condition could be overcome if a preferred performance acceptability list of manufacturers could be prepared, and if these organizations alone received invitations to bid on important castings. In order that such a procedure could operate legally it would be mandatory that compliance be made with the present policy of allowing anyone the right to participate in the bidding on government contracts. This could be done by giving to all manufacturers the privilege of establishing themselves on the performance acceptability list prior to invitation to bid.

By performance acceptability, it is meant that each manufacturer must show his ability to produce sound castings of the same general type and design as those to be ordered; for example turbine casings, major hull castings, etc. In more detail, a plan could be shaped somewhat in the following manner: The Navy could arrange for representative plans to be available for each type of important casting. Thus, there could be acceptable lists for turbine casings, high pressure steam castings, sternposts, struts, stems, rudder castings, and so forth. A manufacturer could qualify on one list or on all lists as he desired, providing he could produce a sound representative pilot casting of that special type. These pilot castings would be inspected by the Navy, that is, radiographed or cut up, and, if such casting proved to be sound and otherwise acceptable, the manufacturer could be placed on the list of producers from whom bids could be accepted.

Such a purchase procedure would have several advantages. In the first place, the Navy would profit because it would at all times have experienced manufacturers producing castings with which they are familiar since it has been shown that at present the best castings are produced by those organizations which have had experience with identical or similar types of castings. A further direct benefit would be achieved by the Navy since the higher standards attained by the product with minimum rejections would allow arrangement of shipbuilding schedules with a greater degree of certainty. Concerning this latter point, the writer knows of a case where the Navy Department awarded a contract to a bidder whose bid was considerably below the other bidders. A year later the Navy had not accepted a single casting from the organization awarded the contract though more than a hundred large castings had been made. The small saving that was thus obtained on the original purchase was

lost a thousandfold due to the time and expense of machining defective castings found unacceptable, and the serious interference with production schedules of the shipbuilding yards.

The steel casting contractors would also benefit as it would prevent the acceptance of bids which are ridiculously low resulting in the loss of considerable time and money because all the manufacturers on the acceptable list would be familiar with costs of production and with the troubles that may be encountered in making acceptable castings. It would also do more, it would establish the manufacturer as a reputable producer in the eyes of the public, which to a progressive organization should be of considerable value.

The plan could be worked in such a manner so as to keep the manufacturers alert to their responsibilities by taking their names off the preferred listings if subsequent examination of their castings showed they were habitually unsound or nonhomogeneous. This would force such a manufacturer to comply again with the performance acceptability tests if he desires to participate once more in Navy work.

In addition to the advantages to the Navy and to the individual manufacturer such a plan would benefit the steel casting industry as a whole for it would undoubtedly result in higher grade products and, through correlation of ideas, help solve some of the important problems which are prevalent within the industry; and, most important of all perhaps, restore some of the lost confidence to the users in the integrity of steel castings for use in vital parts of important designs.

DISCUSSION OF PRECEDING PAPER ON "STEEL CASTINGS" BY LIEUT. C. W. BRIGGS, U. S. N. R., MEMBER.

By P. E. McKinney, Member.*

The author has selected a subject which is of timely interest in view of present-day requirements for light-weight construction for Naval vessels where soundness and reliability of all parts is imperative.

Notwithstanding recent developments in welded construction resulting in substitution of weldments for parts formerly produced as castings, there are many parts where steel castings are fundamentally the correct and practical application.

Among steel castings entering into the construction of Naval vessels, those for the hull structure present fewer fundamental difficulties than castings subjected to steam pressure such as turbine casings, valves, etc. In the case of hull castings it is usually practical to so design them as to afford a reasonable degree of symmetry and thereby minimize the foundrymen's difficulties. The problem with steam pressure castings for Naval vessels is far more difficult as the necessity for placing a number of separate units in a limited engine room space involving accessibility of all units, requires placing of steam connections, outlets, etc., in positions on the individual castings that are not conducive to simplified foundry practice.

Much has been accomplished in the past few years through cooperation between designing engineer and foundryman in adapting design to meeting the foundryman's requirements, but with the greatest measure of cooperation we will never attain a condition where the production of many types of steam and pressure castings will not be attended with serious problems and difficulties.

We can readily concur in the statement of the author that lack of proper equipment is not as prominent a contributor to unsoundness of steel castings as is the lack of application of fundamental

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concepts but we cannot agree that foundrymen generally have ignored these fundamentals in the development of their technique.

The results of fundamental research such as is being conducted by the Naval Research Laboratory on the characteristics of liquid and solidifying cast steel, are being closely followed by wide-awake steel foundrymen and are being practically applied in improvement of technique. The official A. F. A. exchange paper presented to the Institute of British Foundrymen by Mr. Geo. Batty entitled "The Influence of Temperature Gradients in the Production of Steel Castings" is an excellent example of the trend among progressive American foundrymen. We can look forward to a greatly stimulated interest in such developments.

Even with the fullest application of scientific control of foundry operations, we cannot ignore the element of experience and familiarity with any particular type of casting as an important factor in the production of sound material. In many cases the exigencies of service requirements make it impossible to develop a design embodying ideal foundry conditions, in which cases the foundryman's experience with the particular type of work enables him to surmount difficulties which, to the inexperienced, would appear impossible. In such cases, the use of pilot castings to be cut up for purposes of internal examination as a guide to correctional means, is entirely justifiable and not an indication of inefficient foundry planning.

Radiographic inspection of castings affords an excellent method for non-destructive testing of castings and is a valuable aid both to the foundryman and user of castings when results are properly interpreted. Radiographic inspection is, however, not an infallible guide to soundness and suitability of castings for service, particularly where high steam pressure is involved. Instances have been noted where slightly spongy internal areas, which could not be identified as harmful by radiographic examination, have developed leakage in service pressure tests.

In the case of some types of steam pressure castings it would be quite hazardous to proceed with quantity production based on radiographic examination of a pilot casting and without awaiting results of rough machining or pressure testing.

In the matter of purchasing methods, we all realize that the Navy methods are unique and very different from general commercial

practice. Most commercial concerns requiring high quality steel castings confine their inquiries requesting quotation to those producers who have either previously furnished to them satisfactory products or have established to the purchaser's satisfaction their ability to produce a satisfactory result. In practically all cases, enough sources of supply are available to insure keen competition on prices and time of delivery. In event of the customer's detail requirements being impractical, exceptions can be taken or constructive suggestions for changes can be made a part of manufacturer's quotation without penalizing him for an irregular bid.

In the case of Navy purchases of similar material, quotations are solicited through advertising and bidding schedules which are sent to any individual requesting same. The bidding blanks contain information as to number of castings required, name of castings, estimated weight, drawing number and specification involved and detailed instructions on general bidding requirements. Bids are accepted from any manufacturer of steel castings or middleman who files the necessary bond and properly fills out the bidding form.

The elapsed time between dates of advertisement and opening of bids is usually ample for a bidder having experience with the particular type of casting properly to appraise the requirements and submit an intelligent bid. On the other hand, a bidder unfamiliar with the exacting requirements may not have ample time to study the drawings and specifications and fully familiarize himself with the difficulties. Under such conditions low bids are submitted without a sufficient knowledge of the problems involved and through lack of experience the contract is an unsatisfactory one to both parties, resulting in serious delays and machine shop costs to the customer and heavy financial losses to the contractor.

Much of the criticism that is heard about the unreasonable severity of Navy inspection emanates from sources that have, through lack of knowledge of the necessarily exacting requirements, accepted contracts at prices far below actual production costs.

It is realized that all purchase requirements of the Navy must be open to fair competition by all competent sources of supply. Obviously, no vendor would undertake a contract under which he would suffer financial loss if he could foresee such circumstances.

It appears that much might be accomplished by furnishing to prospective bidders more information than is now available as to the character of product required with suggestions that before undertaking to bid they investigate methods of inspection and the finishing of castings as ordinarily practiced in the building yards.

Attempts by purchasing agencies of the Government to develop a list of steel foundry concerns who, after deliberate review of detailed requirements, would express themselves as interested in becoming sources of supply, would probably go a long way toward voluntary elimination of firms not equipped to handle the product in question. Surveys of this kind made in advance of actual need would permit prospective bidders to make a more deliberate survey of the situation than is possible in the short time available after bids are invited on a prospective purchase.

The suggestion of the author for the establishment of performance acceptability ratings for casting producers, appears to have attractive features. If such a method could be practically developed, it would not only protect the Government against serious delay and cost through elimination of unsatisfactory sources of supply but would also protect prospective bidders against heavy financial losses by affording them information as to their ability to fulfill a contract through experience on one test casting rather than through unsuccessful attempts to execute a contract for a number of castings.

Such a method would have to be so regulated as to provide a classification of test castings to represent fully the various basically different types of product and ample discretion would have to be exercised in determining what constituted satisfactory performance as demonstrated by the test of sample casting.

The question naturally arises as to what sample castings would adequately represent the types of castings contemplated. Unless this feature was very definitely covered, the establishment of approved lists in advance of actual need might lead to serious confusion in selecting approved sources of supply and controversies at the time of evaluating bids.

Some of these difficulties might be avoided and the same object accomplished by some plan based on a requirement that before proceeding with production under a contract, pilot castings be made

from each basically different pattern and delivered to the Government. Such pilot castings could be examined, preferably by machining, to approximate finished dimensions or by cutting up so as to expose the internal condition of the castings and thus determine general soundness.

In such a case, provision could be made for cancellation of contract where it was quite evident from examination of pilot castings that the product could not meet requirements. In many cases the inspection of a pilot casting will suggest minor changes in foundry practice or possibly in design, which will overcome the trouble and prevent a repetition of similar difficulties in subsequent regular production.

In the production of intricate castings, such as turbine casing castings, details of design may vary greatly. With the best planned production methods, it is not always possible to obtain sound castings on the first attempt. In the correction of such conditions the value of pilot castings cannot be overestimated.

In carrying out a constructive method such as this, allowable time for completion is a very important factor. In many cases contractors are forced by urgent need of castings, to proceed with regular deliveries on a very close schedule as soon as patterns are received. In the case of a manufacturer having previous experience on exactly similar castings, this may present no great hardship but for other entirely reliable and competent concerns who have not been able to familiarize themselves with detail requirements and difficulties, the allowable time for completion of the usual Naval contract is inadequate for proper planning and execution of the project.

It is believed that with a greater appreciation of the foundryman's problems and the setting up of a procedure for deliberate examination of an initial casting made to new and unusual designs, many more reliable sources of supply could be developed and the Government could be assured of a more generally satisfactory product, and avoid long and costly delays in shipbuilding programs.

ASBESTOS FOR ELECTRICAL PURPOSES.

By C. Huey, Civil Member.*

HISTORICAL.

The term *Asbestos* is derived from a Greek word of the same form, with the inappropriate meaning of *Unquenchable* or *Unextinguishable*. In the light of the present use of the term, the derivation of the word should have been based on the more appropriate meaning of *unconsumable*.

Asbestos is a dense fibrous *mineral* composed of fine, flexible and easily separable filaments of a silky luster (see Plate 1). In common with many other minerals and inorganic substances, it resists high temperatures. But among all the minerals discovered which nature has evolved, even out of elements analogous to asbestos, not one has the fibrous, flax-like structure which, when mechanically macerated, strongly resembles raw cotton, jute, kapok and other *organic* materials used in the textile industries.

The heat resistance and the fire-proofness of asbestos, as we feature it today, have long been known to the civilized nations. It dates back to the ancient Chinese who are said to have woven it into mats for the probable use as heat insulators, and to the Egyptians who are said to have used it as wicks for the oil lamps on altars. It is likely that the mysteriousness of the continually burning lamps when continually fed with oil, has resulted in the application of the word *"Asbestos"* to its literal meaning of *" Unquenchable."*

In medieval times, the Romans are said to have used the fire-proofness properties of asbestos in the form of cremation shrouds where the actual remains of their dead could be sharply distinguished from the ashes of the fuel and which then could be set aside in urns. It is also said that *asbestos* was woven into table clothes which were cleaned after the feasts by throwing them in

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the fire. Because of the difficulty due to the shortness of the fibers, vegetable fibers were sometimes added, as we do today, to make the material more workable. In the fire, the vegetable fibers were then consumed and the pure asbestos fabric remained.

In the many centuries that followed the earlier applications of asbestos, the art was practically lost. About 1700, an Italian professor had his writings printed on paper made of asbestos with the idea of creating imperishable fire-proof documents. This application failed for the reason that although the "paper" did resist the fire, not so the printing. Later, about the middle of the last century, an Italian prepared strong asbestos boards as book covers, with the idea of shielding the inflammable pages of books. Shortly thereafter another Italian proposed the use of asbestos for bank notes. This proposal was not taken seriously as it was realized that the lack of tensile strength of such notes would more than offset the advantage of incombustibility.

In the foregoing abbreviated historical review of the ancient, medieval and pre-modern use or application of asbestos, we find that in the present day applications to the *electrical* art, to which scope of this article is chiefly confined, the same properties are used, *viz.*, heat resistance, flame resistance and by the addition of organic fiber, such as cotton to obtain workability, dependence is placed on the asbestos fiber to maintain a serviceable *envelope* after fire has removed the organic materials. The specific application of asbestos to the electrical arts will be discussed in subsequent paragraphs.

THE MINERALOGY OF ASBESTOS.

Chemically, asbestos must always be regarded as hydrous silicate of magnesia, but one in which considerable variations occur, mainly, in the percentage of lime, which may be entirely absent. Asbestos also may or may not contain alkalies or aluminum in *appreciable* amounts as well as iron in the form of ferris oxide or of actual metallic iron. All asbestos has a variable amount of water contained in its structure in the form of latent water (water of crystallization).

The absence or presence of aluminum, alkalies and iron in variable percentages, in combination with the basic silicate of magnesia, together with characteristic percentages of latent water, serves to

determine both the source of the geographical origin of asbestos, its mineral classification and its application to the industrial arts.

The many varieties of asbestos which are found in small or large deposits all over the world, are distinguished and classified along broad lines into two mineral groups known as (*a*) Serpentine (*Oliven*) and, (*b*) Amphibole (*Hornblende*). The Serpentine group includes a *variety* known as Chrysotile (*crys-o-til*) in which variety we are principally interested for *electrical* purposes on account of its great flexibility, heat resistance, spinning qualities and characteristic very small percentages of iron. The group known as Amphibole (*am-fi-bol*) comprises many varieties not usable for electrical purposes on account of either their brittleness, high iron content or both.

Mineralogy distinguishes many varieties of asbestos, which it designates by different names according to the system in which their crystallization occurs in nature. In the following table, the kinds which are of the greatest practical importance to the electrical and mechanical industries are classified according to their qualities and their principal places of deposit:

Mineral Group	*Variety*	*Chemical Composition*	*Qualities*	*Important Deposits*
Serpentine (*Oliven*)	Chrysotile	Hydrated Silicate of Magnesia	Long fiber greatest flexibility and heat resistance; less acid-proof	Arizona Canada Rhodesia Australia Siberia
	Picrolith	Hydrated Silicate of Magnesia	Long fiber very brittle	Canada
Amphibole (*Hornblende*)	Anthophyllite	Magnesia Silicate of Calcium	Brittle acid-proof	Georgia Montana
	Tremolite	Magnesia Silicate of Calcium	Brittle and less heat resistance but acid proof	Italy Africa Balkan States
	Actinolite	Ferril Magnesia Silicate of Calcium	Brittle and less heat resistance but acid proof	North America
	Crocidolite	Ferric Silicate of Sodium	Flexible, little heat resistance acid proof	Cape Colony
	Amosite	Highly ferric	Long fiber fit spinning	Transvaal

The foregoing table clearly shows the necessity on the part of the manufacturers who fabricate raw asbestos into finished products, of having considerable experience and knowledge of the varieties of asbestos, their qualities and their origin. By the same token, it is highly desirable for the purchasers or users of the finished asbestos products, to be informed of the basic qualities and limitations of the many varieties available.

Knowledge of the origin or source such as Canada, Italy, Siberia, etc., which may be listed as the principal source of supply for certain varieties, alone does not furnish conclusive information as to the particular qualities desired for select applications such as required for electrical purposes.

In general, it is to be expected that desirable varieties of asbestos, as for example *chrysotile*, if obtained say from Arizona or Rhodesia, would be of a definite quality and be immediately applicable for the purpose intended. However, due to the fact that the geographical locations to which the many varieties are assigned on the basis of important deposits (see Plate 2), are areas of enormous extent, several or many of the varieties of asbestos have been discovered in each of the areas while new discoveries are being reported every year. This together with the opening up of roads to many previously inaccessible deposits and the introduction of modern mining methods, has made available for the market demand, an increasing supply of every important variety. The geographical location of the deposits, therefore, although an important guide as to the variety likely to be obtained, is no longer conclusive.

By examination of the chemical analyses of the various classes and varieties recorded by many authorities, it will be observed that there is a striking similarity in chemical composition of *chrysotile* asbestos from widely separated deposits, but on the contrary, there is a distinct difference in chemical composition between *chrysotile* and the *amphibole group*. Representative analyses showing the similarities and differences are compiled as follows:

CHRYSOTILE.

	Canada (Thetford).	*Canada (Danville).*
	Per cent	Per cent
Silica	39–43	41.8–42.8
Alumina	1.5–3.5	.....
Iron Oxide	0.2–2.5	2.2–3.7
Magnesia	40.0–41.5	39.5–42.0
Water	14.0–14.5	14.0–14.5

	Russia (Ural).	*Russia (Siberia).*
	Per cent	Per cent
Silica	42.5–43.5	41.5–42.0
Alumina	Traces to 0.5	Traces to 0.5
Iron Oxide	Traces to 0.15	6.0–7.0
Magnesia	41.8–42.6	35.1–36.0
Water	14.3–15.3	16.0–16.5

	Africa (Rhodesia).	*Italy (Cyprus).*
	Per cent	Per cent
Silica	40.0–43.0	40.6
Alumina	0.6–1.7	1.0
Iron Oxide	Traces to 4.5	4.9
Magnesia	38.2–39.6	39.0
Water	13.0–14.5	14.5

	Arizona (U. S. A.)—Typical.	*Africa (Rhodesia)—Typical.*
	Per cent	Per cent
Silica	40.5	40.99
Alumina	0.17	1.03
Iron Oxide	1.80	4.15
Magnesia	42.06	38.53
Water	15.40	13.24

AMPHIBOLE (HORNBLENDE).

	Cape Colony—Crocidolite.	*Transvaal—Amosite.*
	Per cent	Per cent
Silica	50.5–51.5	49.0–53.0
Alumina	.....	5.7–9.4
Iron Oxide	35.5–36.0	34.0–44.0
Magnesia	0–3.0	0.7–6.2
Alkalines	7.5–9.0	0–2.5
Water	3.5–4.0	2.2–3.0

	Georgia (U. S. A.)— *Anthopyllite.* Per cent	*Natal—Tremolite.* Per cent
Silica	56.4	58.8
Alumina	1.2	5.3
Iron Oxide	11.4	.....
Magnesia	28.7	22.7
Lime	1.7	10.6
Water	1.6	0.5

One of the striking things shown by the chemical analyses of the representative varieties, is in the water content. The chemical latent water, water of crystallization or water of composition, all being synonymous terms, exists as part of the physical structure and plays an important part in the flexibility of the fibers. It has been determined by many investigators that the water content of the softer, and more flexible varieties contain, in general, from 14 to 17 per cent, while the less soft and less flexible varieties contain from approximately 10 to 12 per cent. Certain varieties of the *amphibole* group are extremely low in water content (2 to 4 per cent) and are listed as being very hard and brittle. All of the soft and flexible varieties, however, when heated to a high temperature sufficient to drive off the chemical water content, become transformed into a substance which can be readily pulverized by rubbing between fingers.

The connection between the water content and the flexibility of the various varieties of asbestos, has been firmly established in the trade practices and serves as one of the important identifications of the soft and flexible chrysotile variety which consistently contains 14 to 17 per cent water content.

Some asbestos fiber of good chemical composition for electrical use is found in localities where the surrounding rock contains large amounts of magnetic iron oxides or even free metallic iron and it is not practicable to eliminate this undersirable material from the crushed and fiberized asbestos. This factor of free magnetic iron known as magnetite therefore becomes very important in the analysis of asbestos to determine its suitability for electrical use. It does not form a chemical part of the asbestos but is associated with the fibers much like fleas on a dog.

MINING AND EXTRACTION.

Asbestos deposits in the various parts of the world are found in the form of veins in asbestos-bearing mineral rock (see Plate 3). It appears chiefly on the sides of low mountain ranges, or in surface cut-croppings of plateaus (see Plate 4). The mining methods depend largely on labor conditions and on the extent to which machinery is employed. On mountain slopes, it is extracted in terraces or caves hewn into the rock. The work in the open then progresses step by step along perpendicular sunken levels divided into terraces (see Plate 5). Where the deposits are on level ground, excavations are begun in round or angular form and are deepened in open cuttings, like amphitheaters. The pit thus formed is graded at one end, to allow the material to be hauled out (see Plate 6) or, the pit is surrounded by towers between which wire cables are stretched. Trolleys run back and forth along the cables carrying buckets or baskets of the mined mineral out of the pit (see Plate 7).

The mined rock (see Plate 8) is first subjected to a first rough sorting by hand before it leaves the place of its extraction. As far as practicable, adherent unusable rock is cobbed off, then the product is conveyed to a central point to be properly assorted according to the quality and length of the fibers. It is usual to separate the product into two general classes, the pure fibers and those adhering to rock. Each of these classes are subdivided into long, short or very fine grades.

Where modern machinery is available, the rock-borne asbestos is roughly broken up in stone crushers and stored for a period of time to dry out the free water so that the further processing may be effected. The product is then carried through a crushing mill where the rock becomes broken and separated from the fibers (see Plate 9). Modern machines are so designed and operated that the asbestos fibers of the first grade may not be destroyed and thus become suitable only for the manufacture of asbestos boards. The saving of the long fibers combined with the highest attainable *quantity,* is one of the most important problems as the commercial value of the first grade long fiber asbestos is many times that of the lower grade short fiber product.

After the crushing operation, the product is ready for a final forcible separation of the fibrous asbestos from the rock. This is accomplished in a revolving drum-shaped container in which revolves a shaft with a number of arms bearing long sharp-edged teeth or knives. In this process the fibrous mass is freed from the small remnants of rock which it still contains, and at the same time the bundles of fibers are separated or split open into characteristic filaments of asbestos. Plate 10 shows the relative volume occupied by equal weights of unopened and opened asbestos.

It is a curious fact that all asbestos fibers may be " opened up " or subdivided into an infinitesimal number of filaments. The only limiting factor is in the resistance of the fiber to being manipulated or " picked " into smaller divisions, or in the impracticability of human skill to further divide the fibers. One sample of asbestos fiber picked to fine filaments by the aid of needle points, when viewed at 500 magnifications was estimated to measure .000007 inch diameter. Examination of the ends of one of these isolated fine filaments, showed that it was made up of *innumerable* smaller filaments. The " softness " or the " fluffiness " of processed asbestos therefore becomes a matter of the latent water content and the extent to which the mechanical separation is accomplished. Certain varieties of asbestos open readily while others *resist* being opened to the same extent. These factors are associated with the basic varieties of asbestos and serve to further determine the commercial value or use to which they are finally applied.

When the process of final crushing of the stone is completed and the fibers " opened," the material is then passed through shaker-sieves where the rock about the size of grains of corn, drops through as waste, and the light, pure asbestos fibers are blown by compressed air into collecting bins. The rock remaining in the sieves, which still contains some fine fibered asbestos, is carried to additional crushing machines where the remaining fibers are extracted by suction blowers.

The dust arising from the separation processes is extremely troublesome and has led to many ingenious schemes to lessen the hazard and inconvenience to the workers. The use of air suction blowers in many parts of the processes has greatly reduced the annoyance, but even so, the fineness of some of the asbestos set

loose in the processing at the mines or in the factories using raw asbestos, surpasses all imagination. The fibers floating in the air may vary from the visible diameter of a spider's web to sizes a thousandth or a millionth, invisible to the human eye as single fibers, but seen collectively as a foggy haze which settles in every niche and corner of the factory. A wire mesh screen with 1-inch holes, has been observed in a factory where in the course of time the floating asbestos bridged the entire screen with fairylike invisible fibers, which remade the screen into a solid translucent window.

THE APPLICATION OF ASBESTOS.

After the separation, opening of the fibers and grading according to quality and length, the product is ready for fabrication into the many forms of materials as we use them today. Among the important applications for mechanical purposes are: brake linings, shingles, wall-boards, flooring, steam packings, pipe coverings, filters for corrosive liquids, furnace linings, fire-proof clothing, etc. For these uses, asbestos is mechanically combined with various materials to obtain the resultant properties desired. Such materials may be asphalt, rubber, cement, magnesia, saw-dust, cork, cotton and many other ingredients. Plate 11 shows a batch of selected chrysotile asbestos blended with 10 per cent cotton being fed into a carding machine as the first stage in making asbestos roving for electric cables. Plate 12 shows the exit from a carding machine of blended asbestos in the form of a mat being folded and carried on a conveyor to the next process. Plate 13 shows a "cheese" of asbestos roving in which the mat of asbestos has been worked loosely around a cotton thread core to obtain the necessary strength for further fabrication. This roving forms the basis of the dense compact felted walls of asbestos insulation as applied to flameproof cables. Plate 14 shows a number of "cheeses" of asbestos being worked into the form of strong asbestos yarn suitable for the outer braid of a flame resisting electric cable.

For electrical purposes, asbestos for U. S. Navy requirements is used in four principal combinations as follows:

(*a*) Switchboard panels of the larger sizes for mounting electrical apparatus not exceeding 600 volts. In this form, the medium length fiber chrysotile asbestos is used as a matrix with hydraulic

cements, impregnated with water-proof asphaltic compounds. It has replaced the former slate and marble switchboard on account of the greater resistance to mechanical shock.

(*b*) Molded phenolic compounds used in many forms of small electrical devices and accessories requiring some resistance to flame or high heat. In this application, short fiber chrysotile asbestos is used as a matrix and serves to increase the mechanical strength and flame resistance of the phenolic compound. It has, in general, replaced porcelain and other vitreous materials formerly used in the U. S. Navy.

(*c*) Insulation for copper wire used in motor or generator field coils and armature windings, where the operating temperatures are beyond the range of organic insulations. In this application, long fiber chrysotile asbestos, in which a small percentage of cotton may be incorporated to produce a workable roving, is spun on the conductor and felted into an elastic covering with flame and water resisting compounds.

(*d*) Insulated cables for light and power, where high ambient temperature is encountered, such as boiler and engine room spaces on shipboard. In this application long-fibered chrysotile asbestos is felted with a matrix of about 15 per cent cotton and is applied as a protective covering over vulcanized rubber wall or varnished cambric tape which are used as the primary insulation. The asbestos covering is impregnated with flame and water resisting compounds and serves as a secondary insulation after fire has destroyed or carbonized the inflammable primary insulation.

THE PROPERTIES OF ASBESTOS.

In considering the use of asbestos from an engineering standpoint, the basic physical properties should be carefully weighed so that full advantage may be taken of its desirable characteristics with due regard for certain unsatisfactory properties which may result in misapplication.

There is not a great deal of literature available on the technical properties of asbestos and if recourse is made to the adaptations of asbestos as described and catalogued by the various manufacturers of asbestos products, the user may perhaps be misled to some extent unless informed of the desirable and undesirable properties from the user's standpoint.

Let us then catalogue the known properties of asbestos so that in the application, the results to be expected may be predetermined to a degree which will avoid misapplication:

(*a*) *Non-decaying.*—This property possessed by asbestos, is often forgotten in considering application. It is evident that since asbestos in its natural state has existed for periods estimated in millions of years under all conditions of exposure to the elements, the non-decaying property is established to a firm degree which in its application is strongly contrasted with decayable organic materials such as wood, cotton, cork, hemp, silk, etc. The non-decaying properties of asbestos in many applications, may be considered to be of first importance.

(*b*) *Non-inflammability.*—This property, of course, is the one which is the most usual to recognize and associate with asbestos. Being a true mineral, it has no tendency to ignite or burn when held in a flame. The effect, however, of applying high temperature, is to drive off the water of crystallization. Asbestos in this form entirely loses its flexible fibrous property and may readily be reduced to powder. It is stated that Canada *chrysotile* withstands temperatures of 2000 to 3000 degrees F. and that a temperature of 5000 degrees produces no visible effect on some varieties. *Anthophyllite, tremolite* and *amosite* containing low percentages of water, in general, withstand higher temperatures than other varieties. Where the resistance to high temperatures is of first importance, selection should be made of the variety of asbestos of the higher qualification in this respect.

(*c*) *Acid Resistance.*—Certain varieties of asbestos such as *anthophyllite, tremolite, actinolite* and *crocidolite* are highly resistant to acids, alkalies and other corrosive liquids. These varieties have important application in the chemical industries as filters and caulking of apparatus whose contents contain chlorine, sulphuric acid, ammonia, poisonous gases, etc. The *chrysotile* variety used in the electrical arts, however, is not as acid resisting as the amphibole group.

(*d*) *Heat Conductivity and Heat Resistance.*—Asbestos does not have the low heat *conductivity* which is sometimes credited to it. In other words, as a heat *insulator,* it is inferior to such materials as cork, wood, hairfelt, rubber, cotton, wool and many other similar

classes of materials. The value of asbestos for heat *insulation,* is due to its non-inflammability and also to its fibrous structure which permits manufacture into coverings of porous nature containing air with resultant increase in its value as a heat insulator. The degree of heat conductivity or heat insulation obtained from asbestos depends almost entirely on the form in which it is fabricated or the materials with which it is impregnated. In its natural unseparated state, asbestos is a rock-hard material and could not be considered as a heat *insulator* but rather it would be classed as a fair *conductor* of heat, equivalent to natural stone, marble or slate. However, when fiberized and fabricated into one of the many commercial forms such as corrugated asbestos paper, asbestos millboard, magnesia-asbestos steam pipe covering, etc., such materials are classed as heat *insulators* by virtue of the air entrapped in the resulting structure. Air, as we know, has a very high insulating value. Therefore, the actual numerical value of asbestos as a heat insulator depends, within certain limiting values, on the amount of air entrapped in the structure, the commercial structural form, and the heat insulating value of the materials incorporated with the asbestos. In general, the heat insulating value of any asbestos products fabricated for this purpose, is lower than cork, hair-felt or wool. It is for this reason that these latter materials are used for refrigerating insulations and asbestos materials are used only where high heat or flame resistance is required in addition to heat insulation, such as applications for steam pipe coverings or oven linings.

Paradoxically as it may seem, asbestos when used as a flame resistance material for the protection and insulation of electric wires and cables, is so fabricated by tight assembly and impregnating waxes, as to result in a material which has fair heat *conductivity.* The heat conductivity obtained is about equal or inferior to rubber insulation which it replaces when flame resistant cables are required. It is fortunate for the industry that asbestos in the form used for this purpose has heat *conductance* of approximately the same order as rubber; for, if otherwise, the current carrying capacity of the copper conductors would have to be de-rated due to the fact that copper has a large positive temperature coefficient. If asbestos in this application turned out to be a good heat *insulation,* the electrical losses, due to lack of heat radiation, would become

PLATE 1.—THIS SHOWS THE SILKY NATURE OF ASBESTOS FIBERS. HARD AS ROCK IN THE VEIN, ASBESTOS IS SOFT AND FLUFFY WHEN FINALLY FIBERIZED.

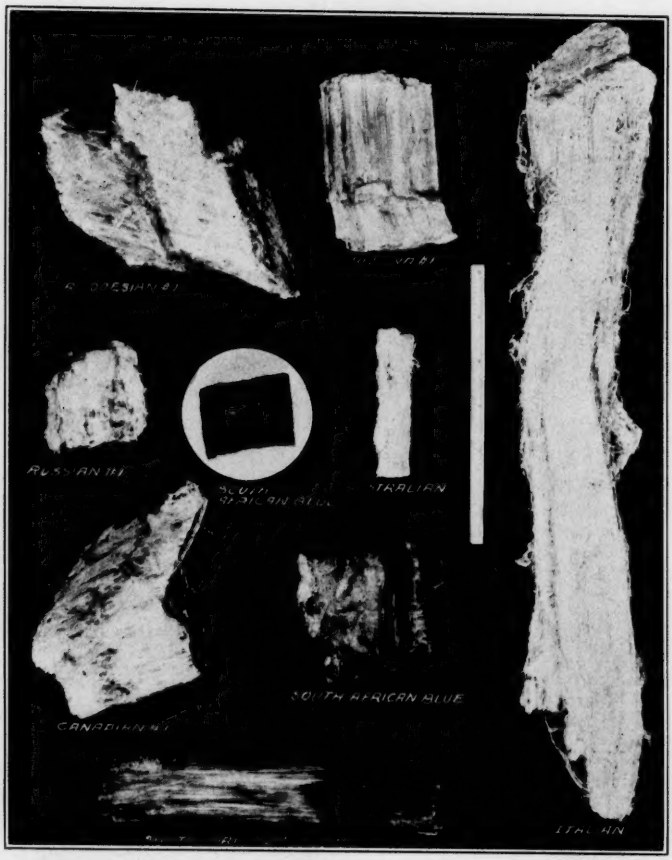


PLATE 2.—REPRESENTATIVE ASBESTOS ROCK FOUND IN VARIOUS PARTS OF THE WORLD.

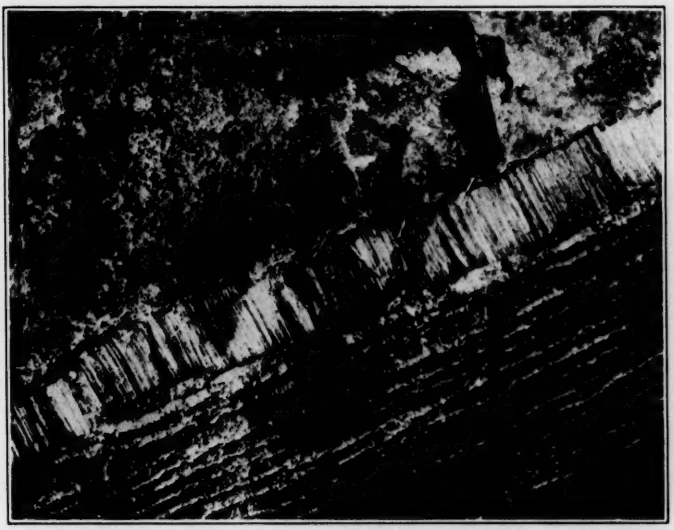


PLATE 3.—ASBESTOS ROCK, INTERSTRATIFIED WITH BROAD AND NARROW FIBER VEINS.

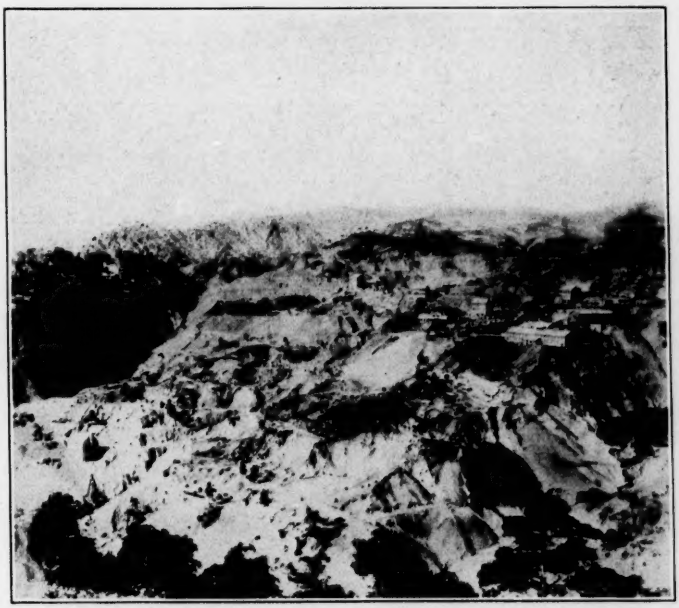


PLATE 4.—AN ASBESTOS MINE BEING WORKED ON A PLATEAU 5000 FEET ABOVE SEA LEVEL.

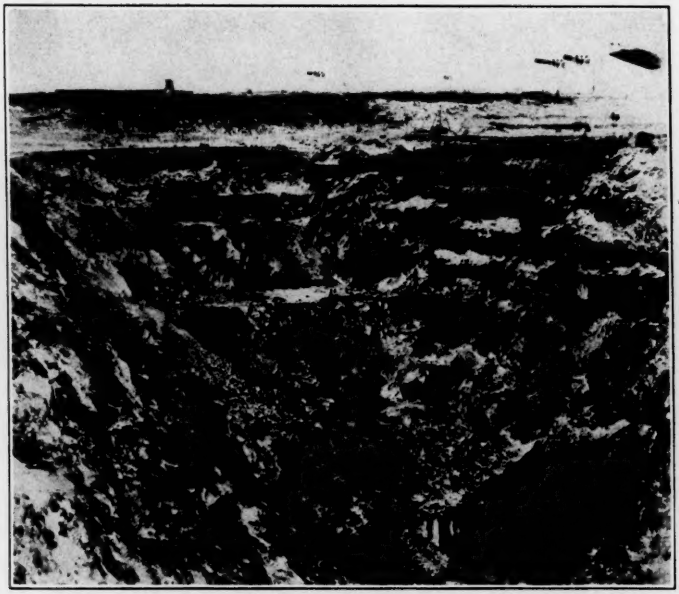


PLATE 5.—A CANADIAN ASBESTOS MINE, ONE OF THE DEEPEST IN THE WORLD.

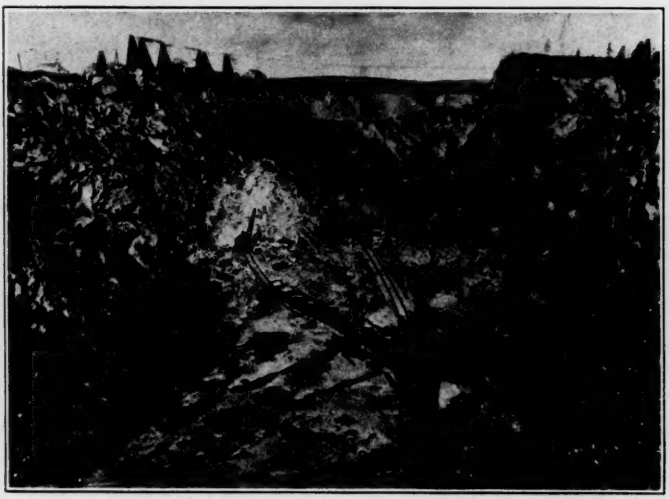


PLATE 6.—AN OPEN TYPE ASBESTOS MINE OPEN AT ONE END TO ALLOW DIRECT HANDLING BY TRACKAGE.

PLATE 7.—AN ASBESTOS MINE WORKED IN THE FORM OF AN OPEN PIT, USING BUCKETS AND TROLLEYS FOR REMOVAL OF THE ROCK.

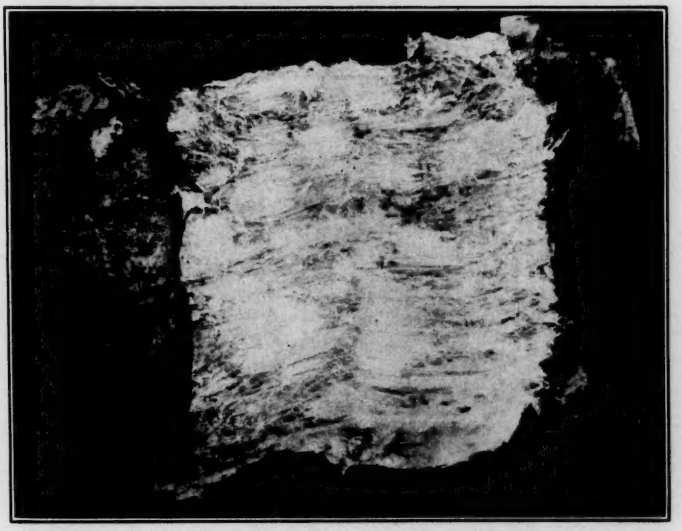


PLATE 8.—A PIECE OF ASBESTOS ROCK JUST AS IT WAS TAKEN FROM THE MINE. FIBERS OF THE ORIGINAL OF THIS PHOTOGRAPH WERE ABOUT 5 INCHES LONG.

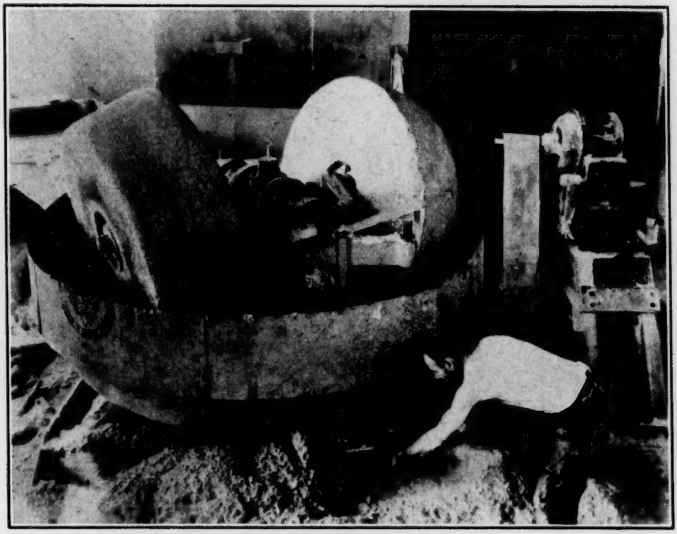


PLATE 9.—CRUSHING ASBESTOS ROCK. GRANITE ROLLS EACH WEIGHING SEVEN TONS RUNNING ON A GRANITE BASE.

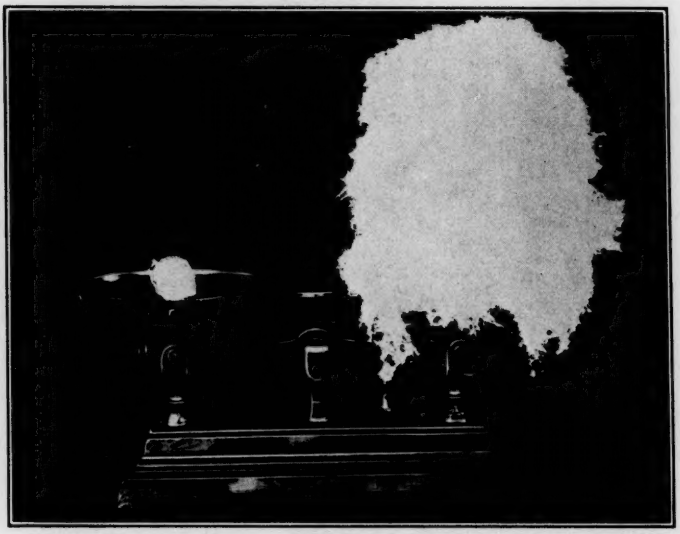


PLATE 10.—THIS SHOWS THE RELATIVE BULK OF ASBESTOS IN THE NATURAL VEIN OR ROCK COMPARED WITH AN EQUAL WEIGHT OF ASBESTOS WHICH HAS BEEN FIBERIZED.

PLATE 11.—THIS SHOWS THE INPUT END OF AN ASBESTOS CARDING MACHINE. FIBERIZED ASBESTOS WITH WHICH IS MIXED A SMALL AMOUNT OF LONG FIBER COTTON IS FED INTO THE HOPPER AND THENCE TO WIRE BRUSH COVERED ROLLERS WHICH COMB OUT THE FIBERS.

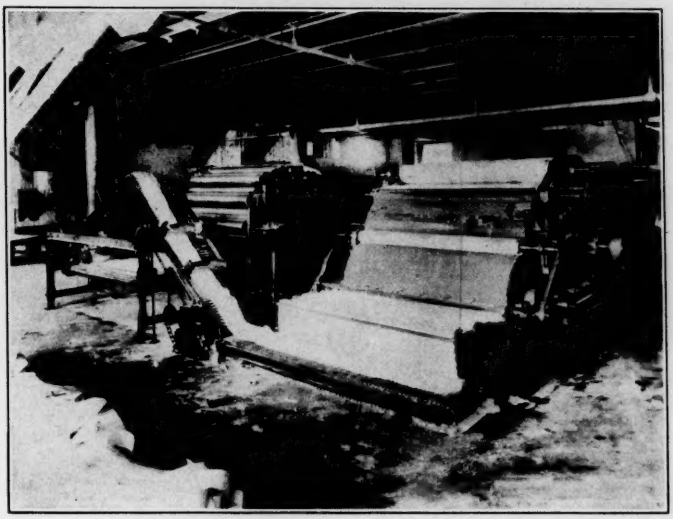


PLATE 12.—THIS SHOWS THE LINK, CALLED THE "CAMEL BACK," BETWEEN TWO CARDING MACHINES. THE FIBER COMING OUT OF THE MACHINE IN THE FOREGROUND HAS BEEN COMBED. IT NOW TRAVELS OVER THE CAMEL BACK IN THE FORM OF A WEB AND IS THEN FED INTO ANOTHER CARDING MACHINE FOR FURTHER REFINEMENT.

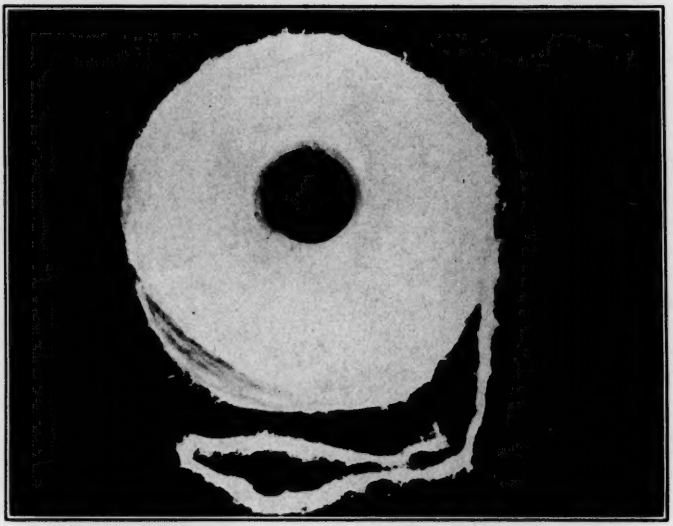


PLATE 13.—THIS IS THE PRODUCT OF THE CARDING PROCESS. SOFT, FLUFFY UNTWISTED ASBESTOS ROVING IS WOUND UP ON THESE FORMS OR PACKAGES CALLED CHEESES.

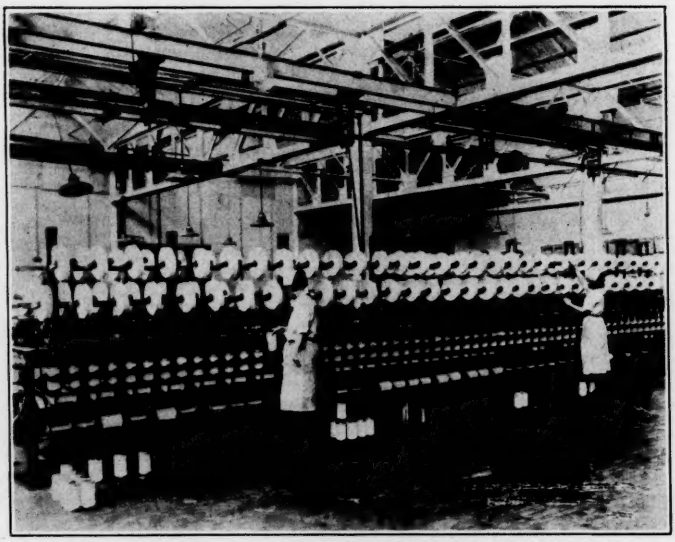


PLATE 14.—ASBESTOS ROVING IS TWISTED INTO YARN ON THIS MACHINE. LARGE PACKAGES OR "CHEESES" OF ROVING ARE MOUNTED AT THE TOP OF THE MACHINE, THE ROVING IS DRAWN OFF THE CHEESE AND RAPIDLY TWISTED AND WOUND ONTO SPOOLS SHOWN NEAR THE BOTTOM.

progressively higher. The de-rating then would be necessary to a point where the electrical losses balanced the radiation factor of the insulation.

(*e*) *Electrical Resistance.*—Certain varieties of *chrysotile* asbestos lowest in iron content, such as is found almost exclusively in selected products of Arizona and South Africa, are the most suitable for electrical insulation. Iron may exist in asbestos as magnetic iron, iron oxide or as a silicate of iron. The presence of magnetic iron directly affects the electrical resistance of the product while in the other forms it is regarded as an impurity more or less inert from an electrical standpoint.

In the use of asbestos for electrical insulation, it is necessary to impregnate the fibers with water-resisting compounds. This is due to the fact that the fibers readily absorb atmospheric moisture. The fibers of asbestos, unlike cotton, silk, wool, etc., do not absorb water into their structure but carry the moisture by external capillary action. For the same reason, any impregnating material applied to asbestos is not absorbed into the fiber structure but dependence is placed entirely on the ability of the impregnating material to seal the entrances to the fiber assembly.

In view of the foregoing, it is difficult to assign definite values of electrical resistance to asbestos unless a definite fabricated product is specified. In the form of switch-board material, composed of asbestos and hydraulic cement, impregnated with asphaltic bitumen, the electrical resistance is rated in terms of breakdown volts per mil thickness (.001 inch). This varies from 50 to 75 volts per mil according to the total thickness of the material compared with varnished cambric 900 to 1400 volts or mica 4000 to 5000 volts per mil.

When impregnated asbestos is applied as a flame-resisting covering for electric cables, the assembly, including layers of varnished cambric tape, is rated at 2000 volts total. After a specified flame application which consumes part of the non-asbestos material, the break-down value per cable averages 900 to 1500 volts total or 45 to 75 volts per mil of composite insulation.

When asbestos is incorporated with phenolic material and is molded into various shapes for lamp sockets, switch bases, etc., the break-down volts average 400 to 500 per mil. This fairly high

value of course is due to the property of the phenolic compound rather than to the asbestos.

The electrical resistance values of asbestos, as indicated from the foregoing, has no definite value in itself, except to indicate that in general it is to be classed as a non-conductor. The properties of asbestos which are exploited in its assembly with other electrical materials are in the main purely mechanical, that is, used for its permanence, flame-resistance, as an inert matrix for impregnating insulating compounds, and as a structural re-inforcement for phenolic molded compounds or other similar composite assemblies.

SUMMARY.

An attempt has been made to indicate the diversified properties of asbestos and its application especially to the electrical industries as applied to materials used in the U. S. Navy. The principal advantages in the use of asbestos for the above purposes may be summarized as follows:

(*a*) Used as a matrix for other electrical materials to increase the mechanical strength and resistance to shock.

(*b*) Used to prevent or retard the total destruction by external or internal fire of basic electrical insulating materials such as: rubber, varnished cambric, cotton, silk, enamel, varnish and phenolic compounds.

(*c*) Used as a secondary insulation when heat has completely destroyed or carbonized the basic electrical insulating materials which, excluding mica and vitreous materials, are invariably inflammable or readily carbonized at fairly low temperatures.

QUICK APPROXIMATION FOR PRELIMINARY PROPELLER DESIGN.

By COMMANDER LYBRAND SMITH, U. S. N., MEMBER.

The purpose of this paper is to present an easy, rapid procedure, readily adaptable to the slide rule, for using the Taylor Method to select a whole series of propellers; each of which will drive a given hull at a desired speed; each of which will differ in diameter, R.P.M. and efficiency; but each of which will be the most efficient propeller for its own R.P.M. (and width of blade).

With such a series of propellers before him the ship designer is better able to select the engine speed which, in combination with the propellers, will give the best overall efficiency for his propulsive machinery as a whole. When an engine speed is set arbitrarily without the study of such a series of propellers it would only be by rare chance that the most efficient combination would result.

For design purposes Rear Admiral D. W. Taylor (C.C.), U. S. N.,[1] has plotted the results of his tests of the "basic series" of propellers in dimensionless form over a quasi-dimensionless basic coefficient "B"; which is a function of speed of advance, propeller revolutions, and power.[2] If shaft horsepower is used, the subscript "P" is attached to "B"; and if "useful" horsepower is used the subscript "U" is attached. Additional subscripts "3" and "4" are used to designate 3 or 4-bladed propellers. Thus B_{u3} is the basic coefficient for "useful" horsepower and 3-bladed propellers.

This article will deal only with the B_{u3} method for the following reasons: First, 3-bladed propellers are generally more efficient and lighter than 4-bladed, and hence should ordinarily be used. Second, "useful" horsepower required to drive a given ship is somewhat

[1] D. W. Taylor, "The Speed and Power of Ships," Ransdell Press, Washington, D. C. (1933).

[2] This coefficient "B" would be truly dimensionless if density of water were included, but as that is nearly constant for practical purposes its inclusion would be a needless refinement.

more definite than shaft horsepower, because "useful" horsepower is fixed by the effective horsepower and hull efficiency (which are quite definite for a given speed and propeller position); while shaft horsepower depends on these factors *and* in addition on the propeller efficiency (which is unknown until after the propeller is designed). Third, brevity—for it will become obvious in the course of this paper that, if any one desired, tables such as those for B_{u3} in this article could readily be made for B_{u4}, B_{p3} and B_{p4}.

The following are the symbols used in this article:—[3]

B_{u3} = basic coefficient for useful horsepower and 3-bladed propellers.
V = speed of ship in knots.
V_A = speed of advance in knots.
w = wake fraction.
t = thrust deduction.
E.H.P. = effective horsepower.
U = useful horsepower.
P = shaft horsepower.
N = propeller R.P.M.
d = propeller diameter, feet.
p = propeller pitch, feet.
a = pitch ratio = p/d.
e_p = "open water" propeller efficiency.
s = slip ratio, true.
M.W.R. = mean width ratio of propeller blades.
B.T.F. = blade thickness fraction of propeller blades.
δ = a dimensionless coefficient.
k = an auxiliary constant.
P.C. = propulsive coefficient.
Ⓝ = approximation of Eggert's cavitation coefficient.
$R.P.M._c$ = R.P.M. at which effects of cavitation become serious.
h = depth factor = 33 feet plus depth propeller hub is submerged.

[3] *Cf.* Harold E. Saunders, "The Prediction of Speed and Power of Ships by Methods in Use at the U. S. Experimental Model Basin, Washington, D. C.," Govt. Printing Office, Washington, D. C. (1933), pp. 49-55.

The following are the basic formulae used in this article:—[4]

$$B_{u3} = \frac{NU^{0.5}}{V_A{}^{2.5}} \quad . \quad . \quad . \quad . \quad . \quad \text{I.}$$

$$U = (\text{E.H.P.}) \div (\text{Hull Efficiency})$$

$$= (\text{E.H.P.}) \div \left(\frac{1-t}{1-w}\right) = \frac{(\text{E.H.P.}) \times (1-w)}{(1-t)} \quad \text{II.}$$

$$V_A = V \times (1-w) \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{III.}$$

$$\delta = \frac{Nd}{V_A} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{IV.}$$

$$(1-s) = 101.33 \div (a\,\delta) \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{V.}$$

$$\text{P.C.} = e_p \times \frac{1-t}{1-w} \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{VI.}$$

$$\text{S.H.P.} = (\text{E.H.P.}) \div \text{P.C.} = U \div e_p \quad . \quad . \quad \text{VII.}$$

Taylor's design data for B_{u3} is presented in the form of contour curves in his Figure 208[5]. A skeleton outline of that figure, with additional dotted lines for explanatory purposes is reproduced herewith as Figure 1.

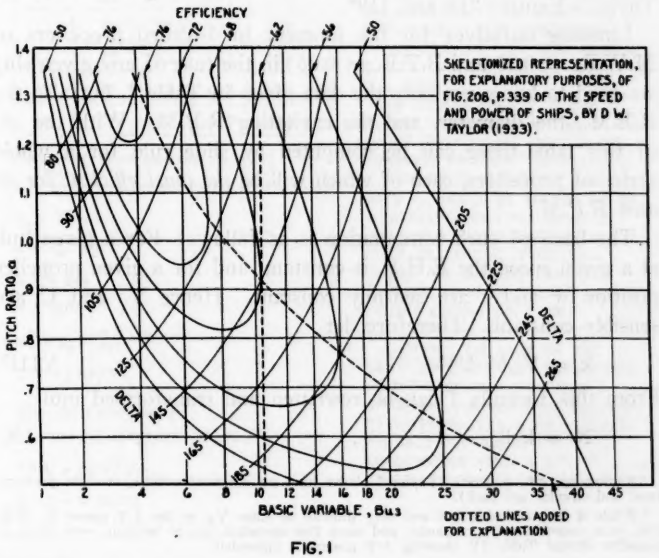


FIG. 1

[4] Taylor, *op. cit., passim.*

[5] Taylor, *op. cit.*, p. 339. *Cf.*, H. F. D. Davis, "Some Comparisons in Propeller Design Methods," JOURNAL OF A. S. N. E., Vol. XLIV, No. 1, Feb., 1932, p. 17, Fig. 3.

It will be seen that for any given B_{u3} (width and thickness of blades remaining constant) there is one most efficient propeller (neglecting cavitation). For example, if B_{u3} is fixed at 10.4 the most efficient propeller is where the vertical dotted line representing $B_{u3} = 10.4 =$ constant is tangent to an e_p contour. *At any other point e_p is less.* At this point of tangency $e_p = .68$; $a = .92$; $\delta = 145$. Formula V shows that the slip ratio "s" is a function only of a and δ. Hence there is a definite value of s corresponding to the most efficient propeller for each value of B_{u3}. Therefore, we can tabulate once and for all, for the most efficient propeller corresponding to any B_{u3}, the values of a, δ, e_p, and s. Such a tabulation (Table I) has been made for a practical working range of B_{u3}; and by use of this table a quick approximation can be made for a whole series of propellers suitable for a particular ship.

Table I, like Taylor's Figure 208, is made only for blades having a mean width ratio of 0.25 and a blade thickness fraction of 0.05. If other values are used e_p and δ change slightly as is shown by Tables II and III, which are condensations and extrapolations of Taylor's Figures 218 and 219[6].

Limiting ourselves for the moment to 3-bladed propellers of M.W.R. = 0.25 and B.T.F. = 0.05; in the case of any given ship we need to know not only the data given in Table I, but also the R.P.M., the diameter, and the cavitating R.P.M. With the aid of this table these can be computed by slide rule for a whole series of propellers, each of which will be *the most efficient for its own R.P.M.*

The basis of such computation is as follows: For a given hull at a given speed the E.H.P. is constant, and for a given propeller position w and t are sensibly constant. Hence V_A and U are sensibly constant. Therefore, let

$$k = V_A^{2.5} / U^{0.5} \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{VIII}^7.$$

From this formula I can be rewritten and transformed into

$$N = k\, B_{u3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{IX}.$$

[6] Taylor, *op. cit.*, p. 108 ("Taylor" blades have an elliptical outline, straight pressure face, and circular arc back).

[7] While it is practicable and not very difficult to raise V_A to the 5/2 power by slide rule, it is somewhat of a nuisance; and since this operation has to be done very often in propeller design Table IV showing 5/2 powers is appended.

BRIEF TABLES AND FORMULAE
FOR
QUICK ESTIMATION OF PRELIMINARY

PROPELLER DESIGN (TAYLOR METHOD)

TABLE I.

B_{u3}	a	δ	e_p	s
4	1.34	88	.778	.142
5	1.21	101	.755	.170
6	1.12	111	.737	.183
7	1.05	120	.721	.197
8	1.00	128	.707	.210
9	.96	136	.694	.223
10	.93	143	.682	.236
11	.90	150	.671	.247
12	.87	157	.660	.258
13	.845	164	.650	.268
14	.82	171	.641	.276
15	.795	177.5	.631	.282
16	.77	184	.622	.288
17	.75	190	.612	.292
18	.73	197	.607	.294

FORMULAE [EXPLANATIONS IN TEXT].

$U = \frac{(EHP) \times (1-w)}{(1-t)}$ DIVIDED BY NO. OF PROPELLERS.

$V_A = V(1-w)$

$K = V_A^{2.5}/U^{0.5}$

$N = K\ B_{u3}$

$d = V_A \delta / N$

$P.C. = e_p \times \frac{1-t}{1-w}$

$SHP = EHP/P.C.$

$\textcircled{N} = 150 + 696(MWR)$

$h = 33 +$ SUBMERGENCE OF HUB (FT).

$RPM_c = \textcircled{N}\sqrt{h}/d$

$(1-s) = 101.33/a\delta$

TABLE II, e_p CORRECTION.

BTF \ MWR	.25	.30	.40	.50
.04	1.003	.993	.965	.958
.05	1.000	.995	.974	.967
.06	.997	.997	.982	.975

TABLE III, δ CORRECTION.

BTF \ MWR	.25	.30	.40	.50
.04	.993	.997	1.003	1.007
.05	1.000	1.005	1.008	1.012
.06	1.010	1.012	1.015	1.017

TABLE I GIVES DATA ON THE MOST EFFICIENT PROPELLER FOR A GIVEN B_{u3} ACCORDING TO THE CHART FIG. 208, P. 339 IN "THE SPEED AND POWER OF SHIPS" BY REAR ADMIRAL D.W. TAYLOR, C. C., U.S.N. (WASHINGTON, D.C., 1933).

THE DATA IN TABLE I IS FOR 3-BLADED PROPELLERS OF "MEAN WIDTH RATIO" [MWR] = 0.25; AND "BLADE THICKNESS FRACTION" [BTF] = 0.05.

IF OTHER MWR AND BTF ARE USED e_p SHOULD BE MULTIPLIED BY A FACTOR TAKEN FROM TABLE II; AND δ BY A FACTOR TAKEN FROM TABLE III. THESE CORRECTION TABLES ARE CONDENSATIONS AND EXTRAPOLATIONS OF TAYLOR'S CHARTS FIGURES 218 AND 219, P. 108.

CAUTION: THE VALUE OF THE CAVITATION COEFFICIENT Ⓝ OBTAINED FROM THE FORMULA OPPOSITE IS A STATISTICAL AVERAGE APPLICABLE ONLY TO THE PROPELLERS IN THESE TABLES. FOR SUCH PROPELLERS THE RPM_c COMES WITHIN ABOUT ± 1½% OF THAT GIVEN BY EGGERT'S CRITERION.

Table IV.

Values of $V_A^{\frac{5}{2}}$

V_A	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
5	56	59	62	65	68	71	74	77	81	84
6	88	92	96	100	104	108	112	116	120	125
7	130	134	139	144	149	154	159	164	170	175
8	181	187	192	198	204	211	217	223	230	236
9	243	250	257	264	271	278	286	293	301	308
10	316	324	332	340	349	357	366	374	383	392
11	401	410	420	429	439	448	458	468	478	488
12	499	509	520	530	541	552	563	575	586	598
13	609	621	633	645	657	670	682	695	707	720
14	733	746	760	773	787	801	814	828	843	857
15	871	886	901	916	931	946	961	977	992	1008
16	1024	1040	1056	1073	1089	1106	1123	1140	1157	1174
17	1191	1209	1227	1245	1263	1281	1299	1318	1337	1356
18	1375	1394	1413	1432	1452	1472	1492	1512	1532	1553
19	1574	1594	1615	1636	1658	1679	1701	1722	1744	1767
20	1789	1811	1834	1857	1880	1903	1926	1950	1973	1997
21	2021	2045	2069	2094	2118	2143	2168	2193	2219	2244
22	2270	2296	2322	2348	2375	2401	2428	2455	2482	2509
23	2537	2565	2592	2620	2649	2677	2706	2734	2763	2792
24	2822	2851	2881	2911	2941	2971	3001	3032	3063	3094
25	3125	3156	3188	3220	3251	3283	3316	3348	3381	3414
26	3447	3480	3514	3547	3581	3615	3649	3684	3718	3753
27	3788	3823	3859	3894	3930	3966	4002	4038	4075	4111
28	4148	4186	4223	4261	4298	4336	4374	4413	4451	4490
29	4529	4568	4607	4647	4687	4727	4767	4807	4848	4888
30	4929	4971	5012	5054	5095	5137	5180	5222	5265	5308
31	5351	5394	5437	5481	5525	5569	5613	5658	5703	5748
32	5793	5838	5883	5929	5975	6021	6068	6115	6161	6208
33	6256	6303	6351	6399	6447	6495	6544	6593	6642	6691
34	6741	6790	6840	6890	6940	6991	7042	7093	7144	7195
35	7247	7299	7351	7403	7456	7509	7562	7615	7668	7722
36	7776	7830	7884	7939	7994	8049	8104	8159	8215	8271
37	8327	8384	8440	8497	8554	8611	8669	8727	8785	8843
38	8901	8960	9019	9078	9137	9197	9257	9317	9377	9438
39	9499	9560	9621	9682	9744	9806	9868	9931	9993	10056
40	10119	10182	10246	10310	10374	10438	10503	10568	10633	10698
41	10763	10829	10895	10962	11028	11095	11162	11229	11296	11364
42	11432	11500	11568	11637	11706	11775	11845	11914	11984	12054
43	12124	12195	12266	12337	12409	12480	12552	12624	12696	12769
44	12842	12915	12988	13062	13136	13210	13284	13359	13434	13509
45	13584	13660	13736	13812	13888	13965	14041	14119	14196	14273
46	14351	14429	14508	14586	14665	14745	14824	14903	14983	15063
47	15144	15225	15306	15387	15468	15550	15632	15714	15797	15880
48	15963	16046	16129	16213	16297	16381	16466	16551	16636	16721
49	16807	16893	16979	17065	17152	17239	17326	17414	17501	17589
50	17678	17766	17855	17944	18033	18123	18213	18303	18393	18484

Thus, having calculated k for a particular ship's speed, we can use a slide rule to calculate quickly the R.P.M. corresponding to any number of values of B_{u3}.

We then transform formula IV into

$$d = \frac{V_A \delta}{N} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad X.$$

and with the fixed V_A, the values of N already computed, and the values of δ from Table I, we can almost as quickly use a slide rule to calculate the values of d corresponding to the several values of B_{u3}.

There remains to be determined the cavitating R.P.M.; *i.e.*, the R.P.M. at which cavitation will become serious. At the present time (1935) the only formula worth anything for predicting the cavitating R.P.M. is that devised by Capt. E. F. Eggert (C. C.), U. S. N.[8] While this formula does not distinguish between the two distinct types of cavitation (rather inappropriately called "laminar" and "burbling"), it does indicate with a tolerable degree of accuracy at what R.P.M. cavitation will beign to have serious effect on thrust, torque and efficiency. The principal factors appearing in the formula are pitch ratio, slip ratio, mean width ratio, depth factor, diameter and thickness ratio of the blade section.

However, the Eggert formula is rather cumbersome to apply for a quick estimate, such as is desired here. An examination of the Eggert formula will show that the thickness ratio has relatively small effect compared to the other four factors. Hence an average value of this factor was taken and it is treated as constant. It has already been shown that for a given B_{u3} and M.W.R. the pitch ratio and slip ratio are fixed. Hence, with a fixed M.W.R. a "cavitation coefficient" was solved for all values of B_{u3} in Table I. It was found to be practically constant, remaining within ± 1 per cent of its average value. The same procedure was followed with other values of M.W.R. While the "cavitation coefficient" varied radically with M.W.R. and did not follow an exactly linear relationship, yet such a relationship remained within about 1½ per cent of being correct. By such a rough statistical method it was found that

[8] E. F. Eggert, "Propeller Cavitation," Trans. Soc. Naval Architects and Marine Engineers, Vol. 40 (1932), pp. 58-64.

an approximate cavitation coefficient could be obtained from the formula:

$$Ⓝ = 150 + 696 \text{ (M.W.R.)} \qquad \text{XI.}^{9}$$

The depth factor (h) and the diameter (d) of the propeller remain to be considered. These are combined by the straight Eggert Method with the cavitation coefficient Ⓝ to obtain the cavitating R.P.M. by the following formula:

$$\text{R.P.M.}_c = \frac{Ⓝ \sqrt{h}}{d} \qquad \text{XII.}$$

It is usually easier to compare propellers for a given ship in respect to cavitation by stating:—

$$\left.\begin{array}{l}\text{Percentage of full power R.P.M. at}\\ \text{which cavitation becomes serious.}\end{array}\right\} = \frac{\text{R.P.M.}_c}{N} \times 100 \qquad \text{XIII.}$$

Example

Given or Estimated for a Particular Hull.

V = 20.6	Number of Propellers = 2
E.H.P. = 4100	Depth of hub
t = .075	below surface = 7.9 ft.
w = .03	

Calculate, using formula indicated in parenthesis.

V_A = 20 (III)	Ⓝ (for M.W.R. = 0.25) = 324 (XI)
$V_A^{2.5}$ = 1789	(for M.W.R. = 0.40) = 428 (XI)
E.H.P. per propeller = 2050	e_p correction (for M.W.R. 0.40) .974 (Table II)
U per propeller = 2150 (II)	δ correction (for M.W.R. 0.40) 1.008 (Table III)
$U^{1/2}$ = 45.94	(Note: Ignore this delta correction as it would make no appreciable difference.)
k = 38.95 (VII)	$\sqrt{h} = \sqrt{7.9 + 33} = 6.4$

[9] Formula XI is NOT applicable to propellers other than those taken from Table I.

B_{u3}	N	d	M.W.R. = 0.25; B.T.F. = 0.5			M.W.R. = 0.40; B.T.F. = 0.5		
			R.P.M.$_e$	$\frac{\text{R.P.M.}_e}{N} \times 100$	P.C.	R.P.M.$_e$	$\frac{\text{R.P.M.}_e}{N} \times 100$	P.C.
			Formula XII $\text{R.P.M.}_e = \frac{324 \times 6.4}{d} = \frac{2072}{d}$	Formula XIII	Formula VI $\text{P.C.} = e_p$ (from Table I) $\times \frac{.925}{.970}$	Formula XII $\text{R.P.M.}_e = \frac{428 \times 6.4}{d} = \frac{2740}{d}$	Formula XIII	Formula VI $\text{P.C.} = e_p$ (from Table I) $\times .974 \times \frac{.925}{.970}$
Assume a series of integers.	Formula IX $N = 38.95\ B_{u3}$	Formula X $d = \frac{20\delta \text{ (from Table I)}}{N}$						
5	194.6	10.37	200	102.7	.720	264	135.5	.701
6	233.5	9.51	216	92.7	.703	287	122.8	.685
7	272.5	8.70	238	85.5	.687	315	115.5	.671
8	311.5	8.21	253	81.7	.674	334	107.1	.657
9	350.5	7.78	267	76.2	.662	352	100.5	.644

The data just calculated is plotted in Figure 2; and, as will be seen, immediately gives a whole series of propellers (not merely the 5 calculated points).

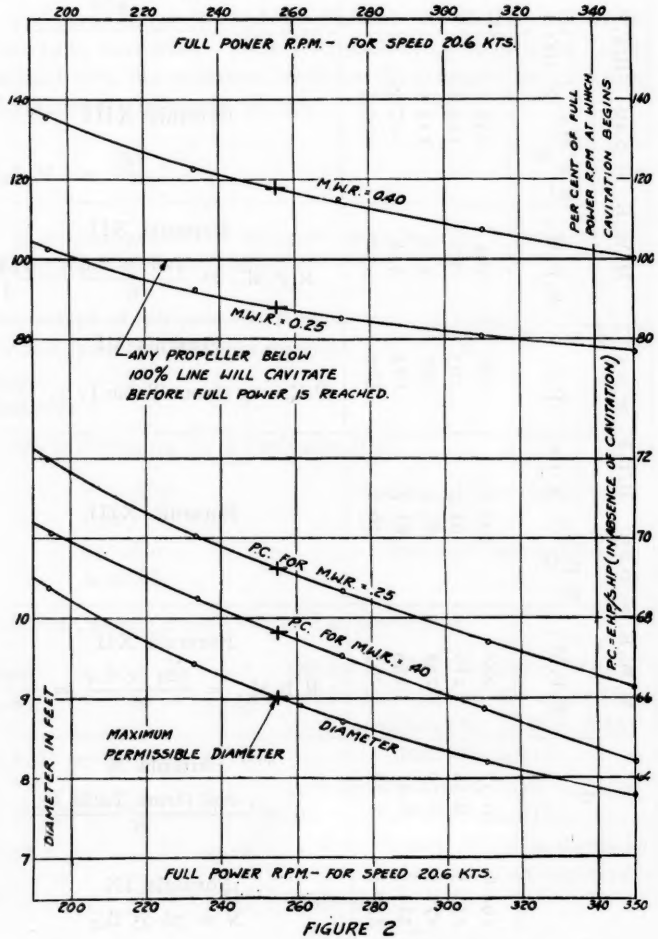

FULL POWER R.P.M. - FOR SPEED 20.6 KTS.
M.W.R. = 0.40
M.W.R. = 0.25
ANY PROPELLER BELOW 100% LINE WILL CAVITATE BEFORE FULL POWER IS REACHED.
PER CENT OF FULL POWER R.P.M. AT WHICH CAVITATION BEGINS
PC. FOR M.W.R. = .25
PC. FOR M.W.R. = .40
DIAMETER
MAXIMUM PERMISSIBLE DIAMETER
DIAMETER IN FEET
PC. = E.H.P.S. H.P. (IN ABSENCE OF CAVITATION)
FULL POWER R.P.M. - FOR SPEED 20.6 KTS.

FIGURE 2

Take the question of *diameter* first. Study of the ship's hull lines indicated that 9 feet was the largest diameter which would permit adequate tip clearance. This point is marked with a cross on the diameter curve at $d = 9.0$ ft.; $N = 255$. A cross is also marked on all the other curves at $N = 255$ to indicate the upper limit which the hull lines permit us.

Obviously then, *the engine designer should hold the shaft R.P.M. down* to 255 R.P.M. *unless he can show definitely that increasing the R.P.M. will increase the engine efficiency enough to off-set the decreasing propulsive coefficient;* or unless decreasing weights would warrant accepting a decreased propulsive coefficient.

Assume that the engine designer accepts the 255 R.P.M.; then what width of blade should we use. Obviously, the narrow blade (M.W.R. = 0.25) gives an appreciably higher propulsive coefficient than the wider; but, looking up to the cavitation curves it is apparent that the narrower blade will start cavitating at about 88 per cent of the full power R.P.M. On the other hand, the wider blade (M.W.R. = 0.40) does not start cavitating until the full power R.P.M. are exceeded by 19 percent. There is no need of such a margin, particularly as it is gained by a loss of propulsive efficiency. An examination of Figure 2 shows that if we take the average of these two M.W.R.'s, say M.W.R. = 0.325 we will still have a little margin on cavitation and will have a propulsive coefficient about 1 per cent better than if we had retained the wider blade.

The pitch ratio ($a = p/d$) is settled by noting in our calculations that a 9-foot diameter propeller must lie between $B_{u3} = 6$ and $B_{u3} = 7$. We turn then to Table I and interpolating get $a = 1.075$ for the proper pitch ratio to give 255 R.P.M. with a 9-foot diameter propeller.

Summing up, the twin propellers we propose to use for driving this ship at 20.6 knots will have the following characteristics:

diameter, $d = 9.0$ feet
pitch ratio, $a = 1.075$
pitch, $p = 9.675$ feet
M.W.R $= .325$
B.T.F. $= .05$
No. Blades $= 3$
Full Power R.P.M. $= 255$

In conclusion, and as was indicated in the title, this paper is intended merely to provide a procedure for quick and easy approximations of preliminary propeller design by the Taylor Method. For the actual final design by that method one should consult Admiral Taylor's book, " The Speed and Power of Ships."

A SOLUTION OF THE M.E.P. PROBLEM.

By Lieut. W. J. Holmes, U.S.N., Member.

The slide rule is a great convenience to the naval engineer but the principle upon which the slide rule is constructed can frequently be used to greater advantage than the rule itself. A good many recurring problems can be solved by use of logarithmic scales. If special scales are constructed the bothersome use of constants is eliminated, the question of the placing of decimal points disappears, scales may be placed in their most convenient relative position, and the whole operation much facilitated.

One of the most interesting of such special applications is in the solution of the problem of M.E.P. limitation of submarine Diesel engines. This problem consists essentially of the determination of the maximum propeller R.P.M. that can be made without exceeding a given percentage of the designed mean effective pressure. At present the solution of this problem involves the use of special cross-section paper, the consultation of numerous instructions, curves and tables, not a little computation, and quite often considerable uncertainty as to the accuracy of the results. Yet the problem is essentially simple, involving only the experimental determination of one constant and the solution of a pair of simultaneous equations.

The horsepower that may be developed by an engine operating at any given M.E.P. may be expressed by the simple equation:

$$H.P. = C\ P\ (R.P.M.) \quad \ldots\ldots (1)$$

Where "C" is a constant for the engine and "P" is the percentage of the maximum designed M.E.P. The constant "C" can always be easily determined by dividing the rated H.P. of the engine by the rated R.P.M.

The relationship between required horsepower and propeller R.P.M. is usually expressed by the equation:

$$H.P. = k\ (R.P.M.)^n \quad \ldots\ldots (2)$$

In the practical solution of this equation "n" is assumed to equal three for all conditions of bottom. Thus, if "k" is determined

experimentally, the horsepower required to make any desired R.P.M. under the existing condition of the bottom may be easily obtained. The quantity " k " may be determined by making a run on the motors and determining the R.P.M. and the horsepower output from the electrical input and the motor efficiency. This procedure is called " running a spot." In the usual graphical solution it is of course unnecessary to reduce the solution of the equation to a numerical answer for " k."

The assumptions regarding " n " are inaccurate, and a knowledge of this fact is important to the practicing engineer. It is unlikely that the determination of the maximum allowed R.P.M. will be affected by an amount greater than four or five R.P.M. by the inaccuracies involved and as the unpredictable quantities of wind and sea might have a greater effect it would appear that the inaccuracies are therefore of no great moment. Reports are, however, sometimes expected to conform to a standard of accuracy not at all warranted by experimental conditions, and a discussion of this assumption is therefore not out of place.

An examination of the standardization curves will disclose that in many cases the quantity " n " differs from three by a small amount. The error introduced by using three is not large but in the method of determination about to be proposed it is unnecessary to make this assumption. Indeed it is easier to use the standardization data that is already available. It is also true that the fouling of the bottom has an appreciable effect upon " n " as well as upon " k." It is now well known that the fouling of a vessel's bottom causes proportionately greater increase in required horsepower at slow speeds than at high ones. The practical effect of this has probably been noted by many submarine engineers. If, when the bottom is quite foul, a " spot " results in a determination of the maximum allowed R.P.M. that is considered higher than desirable the experienced engineer may run another at a lower R.P.M. and this will usually result in placing a lower limit on the maximum speed. Elimination of this difficulty by mathematical means is a little involved. If it is desired for any reason to compare certain maximum R.P.M. limitations it is probably simplest to require that all " spots " be run within certain limitations of speed or horsepower input.

It is apparent that both of the equations with which we have to deal can be solved by the mechanical addition of logarithms. A simultaneous solution of the two equations will determine the maximum R.P.M. that can be made without exceeding any given percent of the maximum M.E.P. In sketch "A" is shown an instrument for the solution of these equations for an engine rated one thousand horsepower at four hundred R.P.M. The theoretical vessel for which this instrument is constructed also requires one thousand horsepower per engine to make four hundred R.PM. with a clean bottom. The coefficient " n " for this vessel is assumed to equal three.

To illustrate the use of this instrument a sample problem will be solved. Assume therefore that a spot has been run and that it required four hundred and twenty-five horsepower per motor to make an average of three hundred R.P.M. per shaft. What is the maximum R.P.M. that can be made without exceeding eighty-five per cent of the maximum M.E.P.?

Revolve the middle dial with respect to the outer dial until the pointer is opposite 85 per cent M.E.P. on Scale A. (If normal operations are to be limited to 85 per cent M.E.P. it will be convenient to provide a hole and pin so that these two dials may be clamped in this relative position.) Opposite the R.P.M. on Scale C may now be read the horsepower available at any engine speed on Scale B. Now revolve the inner dial until 425 " horsepower required " on Scale D is opposite 300 R.P.M. On Scale D can now be read the " horsepower required," each shaft two shaft operation, for any propeller R.P.M. Slide the runner around until a position is found where the " horsepower required " on Scale D is equal to the " horsepower available " on Scale B. Read 368 R.P.M. as the maximum R.P.M. that can be made without exceeding 85 per cent M.E.P.

If it is desired to operate at any other R.P.M., say 350, because of the existence of critical speeds or for any other reason, then read opposite 350 R.P.M., 672 " horsepower required " and 744 " horsepower available." The difference, 72 horsepower, is the horsepower that may be carried as a float on each side. Critical speeds should, of course, be blocked off on the R.P.M. scale in red.

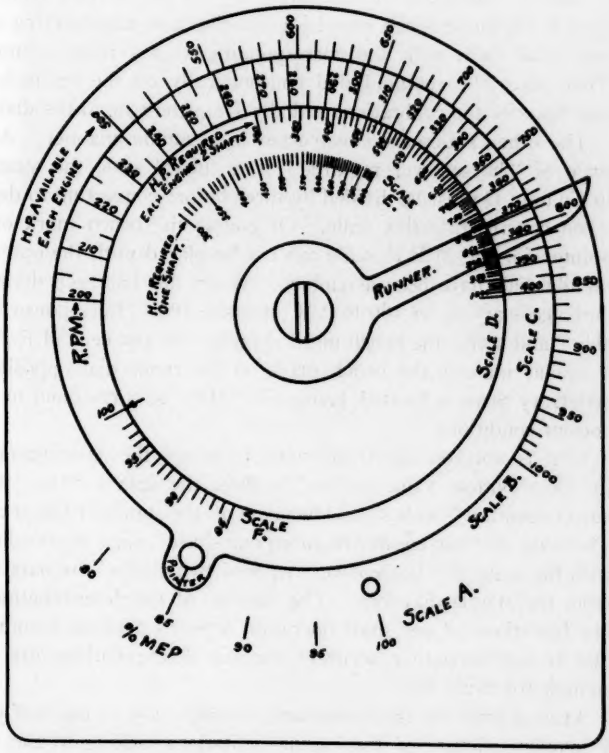
Arbitrary Scale F has been added simply as a convenience in

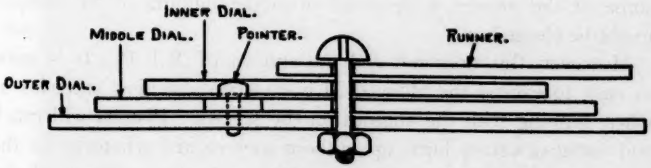
describing the set-up. Thus, the dials may be returned to their present position by simply setting the arrow on the inner dial opposite 100 on this arbitrary scale. Further fouling of the bottom will, of course, result in set-ups with the arrow at lower numerical values on the arbitrary Scale F. The scale of "horsepower required one shaft," Scale E, has been added to indicate the limitations of one shaft operation. The R.P.M. corresponding to the point where the "horsepower required one shaft" equals the "horsepower available" is the maximum allowed speed on one shaft. With 85 per cent M.E.P. this will be found to be 286 R.P.M. The float that may be carried when operating on one shaft may be determined in the manner previously described. For ordinary accuracy it will not be necessary to run an additional one shaft shot.

The instrument may be constructed with a few hours work. The easiest material to work with is one-sixteenth inch celluloid. This material may be cut to shape with scissors, dressed with a file, easily drilled as necessary, and the surface may be prepared to receive ordinary waterproof ink by rubbing with a little fine sandpaper. If desired the lines may be cut with a scribe and the figures added with a small stencil and filled with wax.

The construction of the scales requires a little computation. In constructing Sketch "A," an engine rated one thousand horsepower at four hundred R.P.M. has been assumed. For these figures a scale modulus of fifty gives a convenient length of scale on a ten-inch dial. A ten-inch dial is used as then the compass rose of a small mooring and maneuvering board can be used to lay off the scale in degrees and the actual scales can afterwards be laid off easily on the celluloid dial by simply transposing radially. To construct the scale of "horsepower available" make the following tabulation:

A	*B*	*C*	*D*	*E*
H.P.	Log	Dif	m × Dif	Degrees
	Log A	$B_n - B_1$	50 × C	D ÷ .0875
500	2.6990	0	0	0
510	2.7076	.0086	.43	4.9
520	2.7160	.0170	.85	9.7
530	2.7243	.0253	1.27	14.5
etc.	etc.	etc.	etc.	etc.


H.P. Available Each Engine
H.P. Required Each Engine 2 Shafts
H.P. Required One Shaft.
R.P.M.
Scale F.
Runner.
Scale D.
Scale C.
Scale B.
Scale E.
Pointer.
Scale A.
% MEP


Inner Dial.
Middle Dial.
Pointer.
Runner.
Outer Dial.

Sketch A.

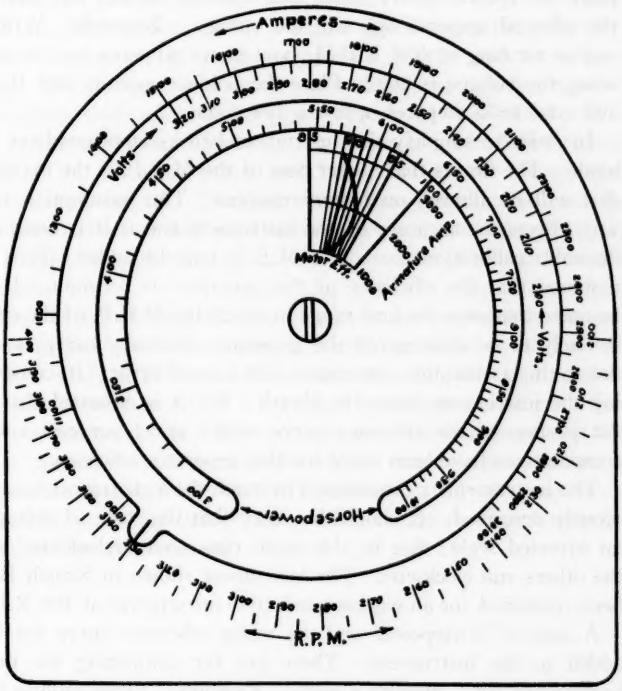
Having completed the tabulation lay off the degrees from Column E on the ten-inch rose of a mooring and maneuvering board and label them with the corresponding values from column A. Then place the celluloid dial concentrically on the ten-inch rose and transfer the calibrations radially from the rose to the dial.

The other scales are constructed in a similar manner. As the scale of " horsepower required " is a cubical scale the quantities in Column D must be divided by three before converting to degrees when constructing this scale. Of course the bench mark on the pointer for the M.E.P. scale can not be placed until the outer and middle dials have been assembled. When this has been done it is only necessary to set 400 R.P.M. opposite 1000 " horsepower available " and scribe the bench mark opposite 100 per cent M.E.P. In a similar manner the bench mark on the inner dial opposite the Arbitrary Scale is located, laying off " 100 " to correspond to clean bottom conditions.

If it is not considered desirable to accept the assumption that the clean bottom value of " n " is three the data for the " horsepower required " scale should be taken off the standardization curve. The scale of " horsepower required one shaft " must be coordinated with the scale of " horsepower required two shafts " by data taken from the standardizations. The validity of the determinations of the llmitations of one shaft operation depends upon an assumption that is not altogether accurate but the determinations are close enough for usual use.

After a little use the instrument becomes easy to use and yields a complete picture of the engine limitations lacking in the other methods. The wise engineer officer will keep a monthly check on his plant limitations and if the method here proposed is adopted some of the present widespread misunderstanding of the subject might be cleared up.

However, this does not end the subject of M.E.P. It is quite as easy to exceed the allowed M.E.P. when charging batteries as when running with the engines on the screws. Pistons will crack and exhaust valves burn up without any regard whatever to the position of the tail clutch. On many vessels the operation of the engines while charging batteries has to be carefully supervised or the M.E.P. will be exceeded during a normal charge.


Amperes
Volts
Armature Amps.
Motor Eff.
Volts.
Horse power
R.P.M.

Outer Dial.
Inner Dial.

Sketch B.

The instrument shown in Sketch B is designed to establish the engine limitations while charging batteries. It is only necessary to place the pointer of the inner dial opposite the R.P.M. and read the allowed amperes opposite the voltage. Example: With the engine running at 330 R.P.M. how many amperes can be pulled when the voltage is 260? Place the pointer opposite 330 R.P.M. and read 1855 amperes opposite 260 volts.

In order to simplify this instrument two assumptions have been made. The first is that 85 per cent of the M.E.P. is the maximum that will be allowed on battery charges. This assumption in no way affects the accuracy of the instrument and if it is considered desirable calibrations for other M.E.P. may be added. It is also assumed that the efficiency of the generator is constant. It will be noted that over the load range in which the M.E.P. of the engine is likely to be endangered the generator efficiency curve is quite flat so this assumption introduces only a small error. In constructing the instrument shown in Sketch "B" it is assumed that this flat portion of the efficiency curve occurs at 92 per cent and all computations have been made for that generator efficiency.

The instrument is constructed in much the same manner as previously described. It should be noted that the scale of voltage is an inverted scale; that is, this scale runs counterclockwise while the others run clockwise. The instrument shown in Sketch B has been computed for an engine rated 1000 horsepower at 400 R.P.M.

A scale of horsepower and the motor efficiency curve has been added to the instrument. These are for computing the motor horsepower for "running a spot." Example: When pulling 2000 amperes at 241 volts, what is the motor's brake horsepower output? Set 2000 amperes opposite 241 volts. On the motor efficiency curve opposite 2000 amperes read 93 per cent efficiency and immediately read on the horsepower scale 601 horsepower. The motor efficiency curve is condensed but it is quite accurate enough for the purpose. Any closer determination of motor efficiency is wasted effort.

If this instrument is to be used by enlisted men it is probably safer to omit the horsepower scale and the generator efficiency curve as they are apt to cause some confusion. However, for use of the engineer these scales are a great convenience. With the two instruments the engineer officer now has a complete description of his

plant limitations and a ready means of solving any problem that may arise in connection therewith. He can now dispense with a multitude of tables, graphs, curves, cross-section paper, parallel rulers and slide rules. With a single figure from the arbitrary scale of instrument "A" he can completely describe and record any set-up. If a trifling complication is not considered disadvantageous the ampere scale and the horsepower scale of instrument "B" may be extended in spiral form, a few points of generator efficiency added to the efficiency curve, and "float horsepower" converted into amperes directly. The instruments may be mounted back to back with a sheet of thin black bakelite as a common inner dial and the whole consolidated into a single instrument of quite small compass.

This method of solution of problems is not confined to the examples given. On some vessels a useful consolidation of the one and two shaft R.P.M.—speed curves may be made in the same fashion and combined with a very handy method of compensation for foul bottom speeds. Such an instrument is quite handy on the bridge and on some, but probably not all, vessels will be found to be accurate enough for all ordinary purposes. A great many problems often solved by curves or by tables can more conveniently be solved by the same means.

PROPULSION MACHINERY FOR NAVAL AND AUXILIARY SHIPS.

By J. H. KING,* MEMBER.

The selection of propulsion machinery for naval purposes is primarily dependent upon military requirements. The choice of machinery must, of course, be based upon the type of ship, its speed, size, space and weight available for machinery, and other special military requirements of the ship in question. Naval requirements are very diverse and it almost goes without saying that machinery suitable for one type of ship may be entirely unsuitable for another type.

That distinguished naval officer, Admiral Mahan, has said that sea power equals naval vessels plus bases plus auxiliary tonnage. For auxiliary tonnage we must depend largely on our merchant marine. The selection of machinery for merchant ships which, in time of war, become troop ships, cruisers, tankers, supply ships, etc., is even more complex a problem because, while such ships must meet military requirements, they must also, in peace times, meet the commercial requirements of the trade in which they are engaged as well as be a paying investment for the owner.

In a purely combatant ship, certain fundamental considerations have quite a different degree of importance than is the case with the merchant ship. While opinions may differ, it is believed that the factors in order of naval importance are, reliability, weight, space occupied, efficiency, cruising radius and cost.

In the merchant ship these factors have a relatively different significance. The primary consideration is the first cost upon which is dependent the carrying charges on the investment. Next is economy which determines the operating cost. Reliability determines the maintenance cost. Weight and space occupied by machinery determine or affect the income from the ship. Perhaps last

* Babcock and Wilcox Co.

in importance is the cruising radius although this will vary with the particular trade route.

The cost of machinery is an item for consideration even in a purely combatant ship, but the cost is secondary to military requirements. A type of machinery that had sufficient military advantages to justify a high first cost might be entirely unwarranted in a merchant ship because of the unnecessarily increased carrying charges. However, these military advantages must be real, based on facts, and justify the increased cost.

The two principal types of propulsion machinery are steam equipment and Diesel engines. The progress in Diesel machinery has been such that it is today quite suitable and satisfactory for specific installations. On the other hand, the marked progress in the development of steam machinery had led to increases in efficiency and economy that hitherto were not deemed possible or feasible.

Any discussion about steam and Diesel driven ships is highly controversial. Certainly no other engineering subject has been so fraught with propaganda, misinformation and inaccuracies. Outside of purely technical magazines, or the transactions of various engineering societies, one rarely finds articles or stories about modern steam machinery. On the other hand, how frequently does one see articles about Diesel engines in the newspapers and glowing stories in Sunday newspaper magazine sections and other purely non-technical weekly and monthly magazines?

Aside from this inspired fiction, the Diesel engine unquestionably has advantages for certain installations. Steam machinery likewise has its advantages and disadvantages. However, a serious engineering consideration of this subject requires a thorough and accurate comparison of all the facts placed on a basis that is really comparable.

The selection of propulsion equipment is a serious subject for those who are charged with the responsibility for designing and specifying ship machinery as well as for its operation. It seems appropriate, therefore, to give consideration to various factors that should be carefully evaluated in making a comparison between the two types of propulsion in order to reach sound conclusions.

FUEL.

Military necessities unquestionably require the use of oil as fuel for naval purposes. The supply of oil available in crude form in this country, including the restricted naval reserves, probably requires no concern in regard to an adequate supply of basic crude. As is well known, crude oil furnishes gasoline, lubricating oil and the various grades of fuel oil. In time of war, there will undoubtedly be a very large and heavy demand for gasoline for various military purposes, both on land and in the air. The amount of gasoline to be obtained from a given quantity of crude oil is dependent upon the extent to which the crude oil is distilled and cracked.

While there are some dissenting opinions, most technologists agree that the Diesel engine requires a much lighter oil than the oil that can be satisfactorily burned under boilers. This Diesel oil which is largely a distillate, can be cracked further to obtain additional supplies of gasoline. The residue from this cracking process is boiler fuel and has no other useful purpose.

Therefore, from a standpoint of availability of fuel supply, it would seem that the military advantage of using steam machinery that can use practically any grade of oil in the boilers and can in an emergency use powdered coal or other types of fuel, has a material advantage over the Diesel engine which requires a fuel that may also be urgently required for other necessary military operations.

Fuel oil is normally classified into six grades. A. S. T. M. (American Society for Testing Materials) Grades 1, 2 and 3 are distillate oils, Grade 1 corresponding, roughly, to kerosene. Grades 4, 5 and 6 are residue oils and correspond, respectively, to the old Navy classification of Bunker A, B and C.

An attempt has been made both by the A. S. T. M. and the Federal Specification Board to set up specifications for each grade and, while these specifications are generally followed, experience has shown that oils of a given grade do vary and at times to a marked degree. This is due partly to the properties of the crude oil, to the care used in blending and, in some cases, to the supply and demand for gasoline and other distillate oils. Therefore, for one or more reasons the quality of different grades vary and cases

are found where a Grade 6 oil will result in different operating conditions in one boiler and not in another. Probably this variation in quality also accounts for Diesel engines occasionally operating for a time on heavier grades of oil than can ordinarily be used without excessive maintenance.

Today, due to supply and demand, oils of various grades, and especially bunker oils, are much better in quality than was the case a few years ago. This is largely due to the reduced amount of cracking done to the oils before removing them from the stills for blending and also to some extent to the change in percentages of the blends used.

The modern high speed Diesel engine requires oils of the Nos. 1, 2 or 3 grade. It is practically impossible to expect to obtain satisfactory results with these engines if oils of No. 4 or heavier grades are used. This was clearly brought out at the Oil and Gas Power Division meeting of the American Society of Mechanical Engineers in December, 1934.

A boiler can use any available grade of oil and has a distinct military and commercial advantage over the Diesel engine in this respect. It is, of course, true that difficulties have been encountered in boiler furnaces in some cases when burning the heaviest grades, but these difficulties have been largely overcome and can be eliminated.

From a strictly military viewpoint, the cost of fuel is relatively unimportant if there is a distinct advantage to be gained by the use of an expensive fuel. Where such advantage is not granted, it is submitted that fuel costs are of concern from the standpoint of funds available in naval appropriations for expenditures for fuel during fleet training and battle practice. On the other hand, fuel costs are so important in the merchant ship that it is desirable to discuss some of the reasons for the cost of various grades of fuel oil.

The price of fuel oil is based upon the economic factors that control supply and demand. The demand for gasoline, which brings a higher price than other fuel oils, governs very largely the degree to which the crude is distilled and cracked. The lighter oils are the distillate grades required for Diesel fuel, industrial purposes, furnace oil for house heating, etc. The price of this oil

is therefore affected by the demand for gasoline as well as the demand for distillate oils for various purposes.

Boiler fuel is almost entirely the residue from cracked distillates from which additional gasoline has been obtained. A relatively small demand for gasoline results in less cracking, therefore making a larger supply of oil available in the grades suitable for Diesel oil. This grade of oil will therefore demand a lower price. On the other hand, depending upon the demand for boiler oil, the smaller supply of cracked residue available for boiler fuel would increase the price of bunker oils and thereby warrant blending residues with a portion of distillate for sale as boiler fuel.

Government restrictions on production of crudes also affects the price of Diesel and bunker fuel, but the final price will depend on the demand for gasoline and various grades of fuel oils.

The fuel cost for a ship must be considered over the period of the life of the ship. Boiler fuel has varied in price from less than half up to three-quarters the price of Diesel fuel. Since fuel costs are of prime importance to the merchant ship owner, this subject requires careful consideration in selecting machinery.

RELIABILITY.

One of the prime necessities for naval machinery is that it be thoroughly reliable. The reliability of steam machinery has been established by experience. Of course, failures occur but the nature of the failures and the facilities for repair are such that, except possibly in the rare case of a major failure that amounts to almost a catastrophe, suitable repairs can be readily made at sea at small expense and the effectiveness of the steam machinery can be maintained even under emergency conditions.

The claim has been made that the higher pressures and temperatures being used in present day steam practice result in complications that make the steam plant unreliable. The facts are quite different. Greater care is necessary in design and construction of present day steam equipment. However, very extensive experience with high temperatures and pressures in existing shore plants has definitely shown that high steam temperature and pressure conditions are thoroughly reliable and that the maintenance is frequently less than with older steam practice.

Reference is often made to the upkeep on boilers particularly with regard to cleaning internally and externally. While the Navy was among the first to give attention to feed water problems, it was only a few years ago that the Navy developed a fully effective method of feed water treatment. Through the work of Lieutenant Commander T. A. Solberg, U. S. N., at the Naval Experiment Station under the supervision of the Bureau of Engineering, the Navy now has a method of feed water control that is sound and workable. Careful and intelligent attention to feed water control and proper use of the information and apparatus now available on naval ships should materially increase the number of steaming hours between cleaning periods now required by naval regulations.

In the Merchant Marine, many lines have been giving careful attention to feed water control. In fact, in a number of merchant ships it has been the practice for several years to open the boilers for cleaning only once in six months or once a year. Yet under these conditions very little cleaning is required and maintenance costs are exceedingly low. Unfortunately, some steamship lines still fail to give adequate attention to feed water control with the result that maintenance and frequency of cleaning in their vessels is unnecessarily high.

Furthermore, in industrial and public utility plants on shore using salt cooling water, boilers are run at rates as high or higher than naval ships. These same plants ashore operate continuously for long periods of time at these high rates, a condition that a naval ship rarely encounters. Under a system of rigid and careful feed water control these plants open the boilers for cleaning at intervals of from six months to a year, or longer. In one particular plant, of which there is record, the boilers operate at a rate of over 12 pounds of water per square foot of heating surface with 30 to 40 per cent make-up feed, a condition no naval ship encounters. The boilers are operated continuously at this rate for five and one-half days a week, being banked over Saturday afternoon and Sunday, and yet these boilers have operated without trouble for two years without cleaning internally. Another plant has operated at a still higher rating for thirteen months without shutting down for any purpose.

In regard to brickwork repairs, much of this could be prevented by more careful attention. Cold air should not be allowed to rush into the furnace when the boilers are secured. Wall cracks should be filled as soon as they are observed and minor repairs should be made when necessary. Care should be taken to prevent impingement of the oil on the brickwork. Some ships pay careful attention to these details but many ships do not. Furthermore, a higher grade of refractory could be used than is ordinarily the case and a low maintenance cost would result.

Tube losses should be rare occurrences with proper feed water control. But, when failures do occur, the replacement is very simple and inexpensive.

It is of interest to contrast the repairs to steam machinery as above noted with the amount of repairs or renewals necessary with liners, piston rings and exhaust valves and the time required for such repairs in a Diesel engine.

In an article published in the November, 1934, United States Naval Institute Proceedings, the author of which is one of the Navy's Diesel specialists, the statement is made on page 1572 that:

"The Diesel is inherently less reliable than the steam engine or turbine due to the necessary subjection of its more delicate mechanism to the temperature of combustion and high pressure."

On page 1573, this article states:

"Cost of upkeep of the Diesel will always be more expensive than that of the steam plant. The Diesel replaces (in making repairs) expensive machined forgings or castings whereas the steam plant replaces cheap (inexpensive) tubing and brickwork."

Further on, on the same page, the author states:

"In noise and vibration the steam plant shows an undisputed advantage over the Diesel plant."

The above statements are common knowledge and admitted by fair-minded engineers. It is quite rare, however, to hear such frank admissions from Diesel advocates.

Another fact that is generally acknowledged in marine work is that a Diesel engined ship cannot maintain its rated horsepower over any considerable period of time. For that reason, it is quite

customary for the sustained speed of a Diesel ship to be obtained at about 75 to 80 per cent of its designed full power. Furthermore, the Diesel engine has not operated successfully for any extensive peroid of time under an overload condition.

On the other hand, the steam plant can and frequently does operate at its designed full power continuously. Also, it is not only capable but in numerous cases has operated at overloads for long periods of time.

In considering reliability, one therefore has to give careful thought and consideration to the factors noted above.

WEIGHT OF MACHINERY.

In naval machinery it is essential that machinery weights be as light as possible consistent with ruggedness and reliability. In making comparisons, the total weight of main and auxiliary machinery must be included. Furthermore, very careful consideration should be given to the extra foundations and supporting members required by the Diesel engine. These are not only required by the greater weight but also by the vibration and thrust from the Diesel engine.

Weights of both Diesel and steam machinery are being reduced as progress is made in each respective art. The Navy Department has consistently been requiring lighter machinery weights and, insofar as steam machinery is concerned, the reductions have been made without introducing hazards in regard to reliability and life of the equipment.

Diesel engines that have been developed for submarine work are much lighter than engines formerly available. However, these engines are not suitable for naval auxiliary or merchant tonnage. Furthermore, no real measure of reliability of these engines is as yet available.

There is a very great difference between steam and Diesel weights on auxiliary ships. The total machinery wet weight of the steam cargo ship described later in this paper is 145.5 pounds per shaft horsepower wet, based on 6000 shaft horsepower. Based on the 8500 shaft horsepower condition, as later described, the wet weight is 106.7 pounds per shaft horsepower. Very carefully prepared weights on a somewhat similar high speed geared Diesel installation

of a very modern type proposed for merchant work, show a total machinery weight of 206 pounds per shaft horsepower. In both cases the weights include all machinery together with all shafting and propellers. In the case of the steam ship, the machinery consists of thoroughly proven equipment, whereas the Diesel machinery is untried equipment designed to compete with that of the steam ship.

Diesel engine weights per shaft horsepower have been materially reduced in recent years, but this weight reduction is primarily the result of increased engine speed, although some other factors are involved. The highest speed engines with the lowest weight have a distinct hazard in reliability. Furthermore, no really high speed oil engine has run long enough to get a real measure of reliability.

The weight in pounds per horsepower of Diesel engines is proportional to the pounds per cubic inch of piston displacement. This depends upon machine design. The weight is proportional to the displacement, and this is inversely proportional to the product of mean effective pressure and revolutions per minute.

It is recognized that if Diesel engine speeds and mean effective pressures are made high enough and, if by special machine designs, the pounds per cubic inch displacement are made low enough, then Diesel engine weights might be made lower than existing steam weights. In this connection, only the future can tell as to what extent reliability will have been sacrificed in such Diesel engines.

It should also be recognized that if military advantages should require a compromise with reliability to save weight, it is perfectly possible to design still lighter steam equipment which would also retain a measure of reliability superior to that of the light weight Diesel machinery.

SPACE.

The space occupied by machinery is important on all classes of ships, whether they be war craft, auxiliaries, or merchant ships. In purely combatant ships, the space occupied by machinery determines the length and height of protective armor required. Any possible saving in armor plate is most advantageous.

The ingenuity of designers has been steadily decreasing the space occupied by steam machinery and, while great strides have

been made in the past, further savings can be made in future designs by the application of more modern steam machinery now being developed.

Claims have been made that Diesel engines require less space than steam machinery. This does not seem to be proven.

Diesel machinery in merchant ships occupies more space than modern steam machinery. For example, the 6000-shaft horsepower freighter previously mentioned has a machinery space 45 feet long by 37 feet 8 inches wide. The cubic space occupied by machinery is 7.5 cubic feet per shaft horsepower. Compare this space with that occupied by the most recent motor ships as described in the Diesel trade papers. The writer has not been able to find a single motor ship that even approaches the compactness of this steam installation. The nearest approach found to this for similar power is 15.2 cubic feet per shaft horsepower.

EFFICIENCY.

It is recognized and admitted that the thermal efficiency of a Diesel engine is greater than the thermal efficiency of steam machinery. The difference, however, is not as great as most Diesel proponents would have us believe.

The introduction of high pressures and high temperatures in present day steam practice has increased the efficiency of the steam plant materially. Fuel oil consumption has been reduced to a point that is very little more than the Diesel engine.

The maximum thermal efficiency that can be expected from a Diesel engine is about 34 per cent. Based on present expectations, the maximum thermal efficiency for steam is about 32 per cent. Steam installations ashore are in actual operation today and have been for several years, developing a thermal efficiency of better than 30 per cent. While it is not feasible to install the same machinery aboard a ship without modification, nevertheless the principles involved are identical and there is no question but what this high thermal efficiency is perfectly possible of attainment.

One should also realize that efficiency and economy are not synonymous. Highest efficiency does not necessarily mean highest economy. A machine may be highly efficient and yet very uneconomical because of the cost of obtaining that efficiency. The cost may be in terms of dollars or loss in speed due to weight, etc.

CRUISING RADIUS.

Cruising radius is a function of fuel capacity and efficiency of the machinery. In view of the Treaty limitations on tonnage for given types of ships, the weight of fuel and the weight of the machinery must be considered.

From the standpoint of efficiency alone the Diesel engine would have a greater cruising radius. This is undoubtedly a distinct advantage when considered from this basis. However, the greater weight of the Diesel machinery would considerably offset the amount of fuel that could be carried for a limited tonnage. Furthermore, the higher efficiencies that are being obtained with steam machinery today as well as the still higher efficiencies that will certainly be available for future installations, will result in a very slight difference in fuel consumption between steam and Diesel machinery. The weight of fuel and lubricating oils plus weight of steam machinery as against weights of fuel and lubricating oils plus Diesel machinery will probably give the steam ship a greater crusing radius.

An item that is little discussed by the Diesel advocates, and upon which it is difficult to obtain accurate data outside the Navy, is lubricating oil consumption in Diesel engines. From the best available records the lubricating oil consumption varies from about 2 per cent to over 5 per cent and, in some cases, 10 per cent of the fuel consumption. The higher lubricating oil consumption usually results in the installation of new rings, etc., so that an average lubricating oil consumption of 3 per cent of fuel seems reasonable. The weight of this lubricating oil must, of course, be deducted from the weight available for fuel oil.

In a steam plant where the turbine is designed for a maximum efficiency at full power, the efficiency falls off at lower powers. As a result, the oil consumption at cruising speed is higher than at full power. A Diesel engine on the other hand has practically a constant fuel rate over all powers. This is a decided advantage.

Consideration has been given to the installation of a Diesel cruising drive on steam driven ships. While such a construction would undoubtedly decrease the total fuel consumption of present ships and somewhat increase the crusing radius of the ship, nevertheless this would involve greatly increased weight due not only to the

added weight of the cruising Diesel but also to the considerable increase in weight of foundations and supporting members. Furthermore, there would be added complication by the necessity for carrying two kinds of fuel oil. The hazards involved in this, plus the acknowledged hazards in reliability of the Diesel engine, indicate that at least for the present the Diesel cruising unit is not a practicable consideration.

In this connection, it is interesting to recall the great publicity and acclaim given the German pocket battleship *Deutschland* which is fitted with Diesel engines. It is of greater interest to note that notwithstanding reports to the contrary the newer German battleships, now under construction, have abandoned the Diesel engine and are to be equipped with high pressure and high temperature steam machinery.

One of the great needs of the Navy today is auxiliary tonnage of adequate speed. It does not appear feasible for the Navy to construct or operate in normal times the ships that would be needed in a national emergency. For that reason the Navy is vitally interested in the construction of merchant ships of all classes, particularly tankers and cargo ships that have a speed of at least 16 knots and are capable in an emergency of maintaining 18 knots or better. Such ships should either be built originally with sufficient power for 18 knots or at least fitted with machinery that can easily and quickly be modified to provide the higher speed.

A design of ship that meets the above requirements and also demonstrates what can be obtained by careful analysis in the selection of machinery and the application of sound engineering, is well exemplified by the following:

Through the courtesy of the Waterman Steamship Corporation, the following contains a general description of a standard cargo ship that has been designed by Mr. W. P. Spofford, Manager of Engineering of that company. The design is unique in its compactness and light weight of steam machinery and the principles involved in the machinery layout have all satisfactorily withstood the tests of actual experience at sea and are in no sense experimental. Not a single factor of reliability has been sacrificed. Particular care has also been taken to provide that every major part of the machinery is accessible for overhaul.

The machinery layout is of special interest in that it is conservatively designed to be capable of a sustained speed of 16 knots and can, with slight modifications plus a new propeller, be quickly modified to provide a sustained speed of 18 knots if required for naval auxiliary purposes. The design is of particular note in that it is also suitable for a tanker of the general type required by the Navy. Certain particulars relating to the hull details are of sufficient interest to warrant mention as being of interest from a ship owner's viewpoint as well as from a naval auxiliary standpoint.

The main features from a cargo ship owner's standpoint are:

1. An extremely compact machinery installation, with deep tanks at sides of machinery space, which permits a smaller overall ship for a given capacity, thus simultaneously reducing first costs, and also the power required to drive which results in reduced fixed and operating charges.

2. A simple yet highly efficient power plant, compact in the extreme, easily maintained and especially laid out for fast overhaul. An overall fuel consumption of .632 barrels per mile at 16 knots including refrigeration and passengers. Port consumption approximately 10 barrels per day with winches in operation 12 hours.

3. A pay load of 48 passengers, 60,000 cubic feet of refrigerated space, and 440,000 cubic feet (bale) of ordinary stowage with a cargo capacity of 7000 to 7400 actual tons cargo, in addition to fuel, for the round trip; minimum dues on account of low registered tonnage.

4. An extremely strong hull with particular reference to the following (usually high maintenance) points:

(*a*) Very strong fore peak and bow. The Maier form was chosen largely because it is possible to provide excellent girder strength in spite of the fine lines necessary.

(*b*) A long distance from nose to collision bulkhead—42 feet 8 inches—providing greater safety in the event of collision.

(*c*) An extremely strong No. 1 tank; the curved surface is intended to provide a wiping action when pitching heavily in ballast instead of the direct pounding as on the flat bottomed bows. In addition to shape, the structure forward is extremely deep and strong to provide resistance to damage by heavy seas and also to provide greater safety in the event of grounding head on.

(*d*) A strong double bottom—4 feet deep for the length of the ship—as added strength and also added protection in the event of grounding on the bottom.

(*e*) A very strong after peak and stern with heavy cast steel stern frame with extended arms tying to framing.

(*f*) A machinery space having added protection against collision damage by a deep double skin for full length—10 feet deep on both sides. This same feature provides excellent longitudinal strength at this point.

5. (*a*) Clean square comparatively unbroken stowage from end to end with no hot spots or other conditions limiting the type of cargo in a given space.

(*b*) Three long booms and three winches per hatch. All booms will handle cargo from cars on second track from ship's side having a working reach of 28½ to 35 feet from ship's sides.

(*c*) Additional boom and winch permits simultaneous rigging and working from dock and barge if desired.

(*d*) Minimum lift for all cargo due to chain rail, and all hatches on same deck.

(*e*) Clean unobstructed decks for deck loads.

(*f*) Five approximately equal size holds for equal use of all cargo gear and maximum dispatch.

6. 60,000 cubic feet of refrigerated space costing approximately 4½ barrels of fuel oil per day to maintain average temperatures.

7. High poop and forecastle for relatively dry decks, and as protection to deck loads.

The main features from a naval auxiliary standpoint, in addition to the above, are:

1. A cruising radius of 15,000 miles at 16 knots.

2. A short machinery space which provides a relatively small target for torpedo attack, and is further protected by the 10-foot double skin in the event of a hit.

3. High clean poop and forecastle for gun mounting.

4. Ample space for naval crews.

5. 60,000 cubic feet of refrigerated capacity.

6. The machinery is designed sufficiently conservative so that by changing turbine nozzle block and ship's propeller the power can be stepped up to 8500 shaft horsepower with resulting speed

of approximately 18 knots. Should it be deemed desirable from a naval auxiliary point of view, the turbine and gear can be modified slightly in design so as to make it capable of 8500 shaft horsepower and 18 knots for emergency conditions. In the latter case the weight of machinery is increased approximately 15 tons. In both above mentioned emergency conditions the maximum powers can be safely maintained for periods of two to three years without undue wear and with very little loss in economy.

PASSENGER QUARTERS.

Complete passenger quarters are provided, including public rooms and deck space, for 48 passengers, each room being an outside room with private bath.

PRINCIPAL CHARACTERISTICS OF HULL.

Length overall, feet		445
Length between perpendiculars, feet and inches		409 — 6
Beam molded, feet and inches		57 — 6
Depth to upper deck molded, feet and inches		39 — 6
Depth to tween deck molded, feet		31
Load draft extreme, feet		27
Deadweight on load draft, tons		8400
Gross tonnage, tons		5400
Net tonnage, tons		4100
Speed, normal in service, knots		16
Shaft horsepower in service		6000
Cargo capacity grain (ordinary), cubic feet		484,000
Cargo capacity bale (ordinary), cubic feet		440,000
Cargo capacity refrigerated, cubic feet		60,000
Cargo capacity total bale, cubic feet		500,000
Bunker fuel capacity full, tons		1500
Passenger capacity	48	
Crew—Engine Dept.	8	
Crew—Deck Dept.	11	
Crew—Steward's Dept.	11	
Officers	11	
Total complement passengers, officers and crew		89

MACHINERY.

A brief description of the various machines including heat balance and drawings of the machinery space follow.

The main engine is a special design developed for Mr. Spofford for the purpose of greater compactness and lessened cost. The principles involved, however, have stood the test of thirteen years actual experience and can in no way be deemed experimental.

Boilers are of the type developed for similar reasons when Mr. Spofford designed the seatrain *New York* and seatrain *Havana,* and have proven very successful in service. Air heaters are used both to improve the economy and to reduce heat adjacent to passenger quarters.

Air to the forced draft blower is taken from the hottest point in the machinery space, thereby reclaiming all of the radiant heat losses from the boilers as well as providing cooler operating conditions for the personnel.

The use of a barometric condenser to absorb the generator exhaust at good vacuum is in effect a low pressure heater of extreme simplicity. The device for marine use was developed by this designer and is presently in use with excellent success. In fact, it is about the simplest and cheapest method of improving heat balance in existing ships.

High efficiency generators are used to make this heat balance possible. Considering that these machines are used every day in the year at sea and in port, the added cost of such units is amply justified.

The evaporator is an extremely simple device being simply a flash chamber with external extended surface piping at the feed inlet. When in service the vapor pipe is wide open to the condenser via a 34-foot barometric loop to prevent liquid carryover. Feed is from the condenser overboard pipe always at a temperature within a few degrees of the flash point. The additional heat being supplied by the heat of the machinery space. A feed pump is not required as water flows of its own force. A float control regulates supply and liquid level in flash chamber. Thus no power is required, there are no coils to be cleaned. Blow down is effected by exhaust steam at intervals. This is a patented device. With the use of this

evaporator there is no necessity of carrying fresh water except for drinking purposes.

Steam driven refrigerating machines were chosen because they represent a difficult electric load, being in use simultaneously with the deck machinery about six or seven days out of the year, thus necessitating about 35 Kw. capacity for 2 per cent use. By using steam triple expansion for this purpose as shown in the heat balance, excellent economy is obtained, small generating sets are ample, and the heat balance is undisturbed by this variable load. Freon compressors are used to avoid necessity for separate gas-tight rooms and brine systems. These have been amply tested in service.

The remainder of the machinery is quite conventional except as to selection and arrangement.

The total machinery space is 45 feet long and 37 feet 8 inches wide. Based on 6000 shaft horsepower for 16 knots, the wet weight of all machinery, tools and spares is only 145.5 pounds per shaft horsepower. When developing 8500 shaft horsepower for 18 knots, the wet weight as above is 106.7 pounds per shaft horsepower.

Complete detailed machinery weights are appended. The foregoing quite clearly indicates how satisfactorily the available and proven steam machinery can meet naval requirements for auxiliary ships. Even when compared with a Diesel ship of 6000 shaft horsepower, the advantages of this steam plant are obvious. It should be appreciated that prudent designing would necessitate 20 to 25 per cent more power in a Diesel engine to provide a sustained speed of only 16 knots and that it would be impossible with the same engine to provide a speed of 18 knots.

When all the above facts are considered the claims of Diesel engine proponents are effectually confuted.

DESCRIPTION MACHINERY 9000 D.W. TON CARGO SHIP.

Boilers.—The boilers consist of two cross-drum sectional header type, single pass, oil burning units with interdeck superheaters and superimposed air heaters. The boilers are completely double cased for forced draft operation using a single motor driven blower for both boilers. Two rows of 2-inch tubes and three rows of 1⅛-inch

tubes below the superheater protect the superheater from excessive temperatures; the tube bank above the superheater contains 1¼-inch tubes. The superheater consists of 1¼-inch U bend tubes expanded into forged steel headers located on one side of the boiler.

The generating surface of the two boilers totals 9420 square feet, the superheating surface 1980 square feet and the air heating surface 6060 square feet.

Each boiler is equipped with six soot blowers and four oil burners. Each has double front, bottom, and back designed for forced draft with a single motor driven blower supplying both boilers.

Oil rate at 6000 shaft horsepower = .37 pounds oil per square foot heating surface.

Steam conditions 500 pounds gauge at drum 780 degrees F. total temperature at superheater outlet.

Overall efficiency—boiler, superheater and air heater 85 per cent.

Each boiler is fitted with a desuperheater in the steam drum having a capacity of 5000 pounds of steam per hour.

Main Engine.—Cross Compound Turbines and Double Reduction Gears—6000 shaft horsepower at 105 revolutions per minute.

Water rate 6.9 pounds per shaft horsepower hour exclusive of bleeding.

Steam conditions 465 pounds pressure 770 degrees F. total temperature at H.P. bowl—1½ pounds absolute exhaust.

H.P. Turbine 2000 shaft horsepower at 7000 revolutions per minute driving single train of gears (2000 shaft horsepower per pinion).

L.P. Turbine 4000 shaft horsepower at 4400 revolutions per minute driving double locked train of gears (2000 shaft horsepower per pinion).

Astern turbine in low pressure turbine only 3000 shaft horsepower.

Bleeder points.—Crossover pipe 140 pounds absolute 66 per cent replacement value.

Belt in L.P. turbine 46 pounds absolute—40 per cent replacement value.

Main Condenser.—Single pass surface condenser having streamlined water boxes and piping with scoop type inlet and outlet strainers which enable condenser to maintain partial vacuum with circulator stopped. Condenser has 5050 square feet of cooling surface and is capable of maintaining 1½ pounds absolute pressure when supplied with 11,000 gallons sea water at 75 degrees F. Condenser is directly connected to L.P. turbine with weight of empty condenser taken on springs. Water velocity through condenser 5.4 feet—friction 4 feet.

Main Circulating Pump.—One 24-inch Mixflo volute pump capable of 11,400 gallons per minute against 9-foot total head, efficiency 85 per cent. Driven by a 40-horsepower adjustable speed motor.

Condensate Pumps.—Two—one service and one standby—vertical volute type each with a capacity of 125 gallons per minute against 75-foot total head, and driven by 7½-horsepower vertical constant speed motors. Actual power required at 100 gallons per minute against 60-foot head 5 horsepower.

Air Ejectors.—Twin two-stage jets—first fitted with intercondenser, second stage discharging to deaerating heater. Capacity of each jet 30 pounds per hour of dry air at 1½-inch mercury absolute suction pressure. Steam consumption 75 pounds per hour first stage, 113 pounds per hour second stage. Steam taken from desuperheaters through an orifice providing operating steam of 250-270 pounds gauge slightly superheated.

Auxiliary Condenser.—High vacuum 2-pass surface condenser capable of handling 4000 pounds steam per hour at 28½ inches vacuum when supplied with 400 gallons per minute of salt water at 75 degrees F.

Auxiliary Circulator.—Horizontal centrifugal 400 gallons per minute at 20-foot head—3-horsepower motor.

Auxiliary Condensate.—Horizontal centrifugal—12 gallons per minute against 60-foot head—¾-horsepower motor.

Auxiliary Air Pump.—Twin 2-stage condensing air ejector—75 pounds steam consumption.

Main Feed Pump.—Direct connected turbine driven centrifugal feed pump having a capacity of 140 gallons per minute against 550 pounds pressure. At 105 gallons per minute turbine develops

74 brake horsepower at a water rate of 22 pounds per brake horsepower hour operating at 465 pounds gauge 770 degrees F. total temperature and exhausting against ½ pound back pressure, direct to deaerating heater.

Auxiliary Feed Pump.—12-inch × 8-inch × 24-inch vertical simplex, operating on 450 pounds steam from desuperheaters.

Port Feed Pump.—6½-inch × 4½-inch × 12-inch vertical simplex, operating on 450 pounds steam from desuperheaters.

Fire and General Service Pump.—8-inch × 12-inch × 24-inch vertical simplex, steam and designed for full boiler pressure but normally operated through an orifice at 250-270 pounds pressure.

Sanitary Pumps.—Two—one service and one standby—horizontal centrifugal pumps, 200 gallons per minute at 75-foot head driven by 5-horsepower electric motors. Pumps discharge through refrigerating condensers direct to service tank in double smokestack which is equipped with overflow insuring full water to condensers. Tank in stack is amply protected against freezing. These pumps are also connected to fire line for wash down and general service.

Lubricating Oil Pumps.—Two—one service and one standby—vertical centrifugal pumps submerged in oil, each with 7½-horsepower motor. Normal load when pumping 250 gallons per minute against 50-foot head 5 horsepower.

Fresh Water Pump.—Self-priming horizontal centrifugal—20 gallons per minute at 20-foot head 1-horsepower motor—discharging to service tank in double stack. Equipped with automatic cut out.

Ballast and Bilge Pump.—Horizontal centrifugal self-priming pump having a capacity of 450 gallons per minute with simultaneous 20-foot suction lift and 25-foot discharge head 10-horsepower motor.

Fuel Oil Transfer Pump.—Rotary horizontal pump having capacity of 130 gallons per minute against a simultaneous 15-foot suction lift and 30-pound discharge head—10-horsepower motor.

NOTE: Normally the transfer and ballast pumps are operated from a double throw switch which prevents their operating simultaneously. This in order to maintain fairly steady load on generators, but emergency switches are provided in case both are needed at the same time.

Fuel Oil Service Pumps.—Two—one service and one standby—each with a capacity of 4500 pounds oil at 300 pounds discharge pressure. Horizontal rotary pump each driven by 5-horsepower motor.

Emergency Fuel Oil Service and Transfer Pump.—6½-inch × 4½-inch × 12-inch vertical simplex for use when electric power not available.

Barometric Condenser.—10-inch jet type barometric condenser fitted with single stage non-condensing air ejector. Condenser designed to return all the heat in the electric generator exhaust (under normal sea load) to the feed water and still enable generators to exhaust at 7 pounds absolute pressure, the main engine condensate being the condensing medium. Capacity 50,000 pounds per hour.

Deaerating Heater.—Having a capacity of heating and deaerating 50,000 pounds water per hour from 150 to 210 degrees F.

First and Second Stage Feed Heaters.—Two duplicate surface type heaters each capable of raising the temperature of 60,000 pounds of water per hour 80 degrees F. and designed to operate with a terminal difference not to exceed 6 degrees F.

Evaporator.—Vacuum type capacity 24 tons per 24 hours. Vapor pipe connected direct to main condenser with 34-foot barometric loop to prevent carry over. Water supply led from main condenser overboard pipe with no pump needed. Float control for constant water level. Heat supplied by radiant heat of fireroom. Thus no (otherwise recoverable) power required to operate.

Fuel Oil Heaters.—Two—one service and one standby—surface heaters each having a capacity of 4500 pounds of bunker C oil to be heated from 100 degrees F. to 265 degrees F. when supplied with steam at 46 pounds absolute.

Lubricating Oil Coolers.—Two—one service and one standby—surface type oil coolers—single pass on water side—each capable of cooling 250 gallons per minute of heavy lubricating oil from 140 degrees to 110 degrees F. when supplied with 400 gallons per minute of 86 degrees F. sea water. Friction drop water side 2 feet—oil side 7 pounds. Cooler water supplied by main circulator.

Feed Water Filter and Grease Extractor.—Twin type capable of handling 700 pounds of condensate per hour from oil heaters, etc.

Generators.—Two—one service and one standby—150-Kw. high efficiency geared turbo generators D. C. 230-volt. Having a water rate of 15.9 pounds per Kw. hour at the terminals when operating full load with 465 pounds steam 770 degrees F. total temperature, and 1½ pounds absolute back pressure. Also having a water rate of 20.2 pounds per Kw. hour at two-thirds load with the same steam conditions, but with 3.42 pounds absolute back pressure. Generators exhaust to barometric condenser at sea, and to auxiliary condenser in port.

Ship's Refrigeration.—Two 2-ton motor driven Freon compressors—3 horsepower each. Operating direct expansion to coils in ship's ice boxes—returning through chill rooms. Each unit self-contained with condensers and all fittings. Emergency interconnection located at side of ice boxes.

Cargo Refrigeration.—Four 10-ton direct steam engine driven Freon compressors operating direct expansion to coil rooms in refrigerated holds. Each unit self-contained with condensers, and all fittings. Engines designed to operate on 125 pounds gauge steam pressure and 31 pounds gauge back pressure. Steam is supplied in port through reducing valve, and at sea, steam is supplied from H.P. turbine bleeder and exhausts to first stage feed heater. Water rate for all four engines 2200 pounds per hour.

Refrigerating Blowers.—Four—two in each hold direct motor driven—2 horsepower each.

Steering Engine.—Electro-hydraulic capable of developing 1,600,000 inch pounds torque and of swinging through 70 degrees in 30 seconds. Two hydraulic pumps each driven by 15-horsepower motor. Separate wiring circuits complete from engine room to each motor thus providing complete standby equipment from generator to rams.

Capstan.—One motor driven on poop deck having a capacity of 16,000 pounds at 40 feet per minute—25-horsepower motor.

Windlass.—One motor driven on forecastle capable of lifting both anchors each with 30 feet of chain simultaneously at a speed of 20 feet per minute. 50-horsepower motor.

Deck Winches.—Fifteen 5-ton motor driven cargo winches each with 25-horsepower motor.

HEAT BALANCE, 16 KNOTS, 6000 SHAFT HORSEPOWER.

Main turbine 6000 shaft horsepower × 6.9 pounds per shaft horsepower hour	41,400
plus 6960 × 66 per cent replacement value (bled at 140 pounds absolute)	4,594
2200 pounds steam to refrigeration machine and 4760 to second stage heater plus 2010 × 40 per cent replacement value (bled at 46 pounds absolute)	805
400 pounds to fuel oil heater, 600 pounds to general heating and 1010 to first stage heater.	
Total steam to main turbine	46,799

Steam to condenser at 1½ pounds absolute = 46,799 less 8970 bled = 37,829 pounds. Water from condenser = 37,829 plus 2 per cent for leakage makeup, etc. 760 pounds plus 75 pounds 1st stage air ejector = 37,829 plus 760 plus 75 = 38,664 pounds water at 89.2 degrees F. 1st stage air ejector 75 pounds steam = $\frac{75 \times 1000}{38,664}$ = 2 degrees F. rise = 38,664 pounds water at 91.2 degrees F.

Generator exhausting to barometric condenser 98.6 Kw. at 20.2 pounds per Kw. hour = $\frac{1990 \times 1006}{38,664}$ = 51.5 degrees F. rise = 40,654 pounds water at 142.7 degrees F. = 3.42 pounds absolute pressure at generator turbine exhaust.

2nd stage air ejector 118 pounds plus barometic air ejector 75 pounds = $\frac{193 \times 988}{40,654}$ = 4.68 degrees F. rise = 40,847 pounds water at 147.38 degrees F.

Turbo feed pump 74 horsepower at 22 pounds per brake horsepower hour = $\frac{1630 \times 1080}{40,847}$ = 43 degrees F. rise = 42,477 pounds at 190.38 degrees F.

Drains at 276 degrees F. = fuel heater 400 pounds, general heating 600 pounds 1st stage heater 7970 pounds $= \frac{8970 \times 72.15}{42,477}$

$= 15.2$ degrees F. rise $= 51,447$ pounds water at 205.58.

1st stage heater to raise to 270 degrees F. requires $\frac{51,447 \times 65.24}{927.2}$

$= 3620$ pounds steam at 46 pounds absolute supplied as follows: (Drains from 2nd stage heater $\frac{4760 \times 80}{927.2}$) $= 410$ pounds equivalent, exhaust from refrigerating machinery $= 2200$ pounds leaving 1010 pounds to be bled from turbine for heater in addition to the 1000 pounds bled from turbine at 46 pounds absolute for fuel and general heating.

2nd stage heater 347 degrees F. requires $\frac{51,447 \times 80.5}{867.7} = 4760$ pounds steam at 140 pounds absolute.

Boilers evaporating 51,172 pounds per hour at 500 pounds gauge 780 degrees total temperature and 268 pounds per hour at 500 pounds gauge saturated $\begin{matrix} 51,179 \times 1083 = 55,510,000 \\ 268 \times 885 = 234,525 \end{matrix} = 55,744,525$ B.t.u.'s to be supplied by boilers.

$\frac{55,744,525}{18,500 \times 85} = \frac{55,744,525}{15,725} = 3540$ pounds oil per hour all purposes.

$\frac{3540}{6000} = .59$ pounds oil per shaft horsepower hour all purposes including hotel and refrigeration.

$\frac{3540 \times 24}{350} = 242.4$ barrels per day; $\frac{242.4}{384} = .632$ barrels per mile.

GENERATOR LOAD AT SEA WHEN DEVELOPING 6000 SHAFT HORSEPOWER WITH FULL REFRIGERATING LOAD.

Machine.	*B.H.P. Required.*
Steering Engine	10
Main Circulating Pump	40
Condensate Pump	5
Lubricating Oil Pump	5
Sanitary	5
Fuel Service	5
Ship's Refrigerating Machine	4
Cargo Refrigerating Blowers	8
Fresh Water Pump	1
Forced Draft Blower	8
Lubricating Oil Purifier	½
Bilge and Ballast Pump $\frac{2.4}{24}$ hours at 10 horsepower	1
Transfer Pump $\frac{4}{24}$ hours at 9 horsepower	1½
Total	94 B.H.P.

94 × 112 per cent = 105.25 brake horsepower output necessary at generator terminals.

97.5 × .746 =	78.6 Kw.
Lighting and passenger service load	20 Kw.
Total generator load	98.6 Kw.

SUMMARY OF ESTIMATED WEIGHTS OF PROPELLING MACHINERY; STANDARD CARGO VESSEL—6000 SHAFT HORSEPOWER.

	Pounds.
1. 2 Boilers, including superheaters, air heaters, desuperheaters, air casing, soot blowers and oil burners	281,000
2. 1 Main turbine and reduction gears (6000 shaft horsepower only)	165,000
3. 1 Main condenser	30,000
4. 1 Main circulating pump	7,100

	Pounds.
5. 2 Condensate pumps	1,970
6. 1 Twin, 2-stage air ejector	1,800
7. 1 Auxiliary condenser	3,600
8. 1 Auxiliary circulating pump	855
9. 1 Auxiliary condensate pump	150
10. 1 Twin, 2-stage auxiliary air ejector	1,500
11. 1 Main feed pump	4,600
12. 1 Auxiliary feed pump	3,550
13. 1 Port feed pump	800
14. 1 Fire and general service pump	2,400
15. 2 Sanitary pumps	1,000
16. 2 Lubricating oil pumps	3,560
17. 1 Fresh water pump	200
18. 1 Ballast and bilge pump	1,700
19. 1 Fuel oil transfer pump	1,400
20. 2 Fuel oil service pumps	1,860
21. 1 Emergency fuel oil service and transfer pump	850
22. 1 Barometric condenser	790
23. 1 Deaerating heater	4,800
24. Two stages feed heaters	4,800
25. 1 Evaporator	1,200
26. 2 Fuel oil heaters	1,560
27. 2 Lubricating oil coolers	4,800
28. 1 Filter and grease extractor (twin type)	600
29. 2 Turbo generators	28,000
30. Forced draft fan and drive	1,200
31. Switchboard	2,500
32. Shafting and couplings	94,000
33. Shaft bearings	7,200
34. Propeller	16,000
35. Stern tube	12,000
36. Shaft turning gear	50
37. Lubricating oil centrifuge	600
38. Inspection tank	600
39. Kerosene tank	200
40. Fuel oil meters	200
41. Engine and boiler room spares	8,000
42. Spare tailshaft	17,000

	Pounds.
43. Machinery handling gear	3,000
44. CO_2 extinguishers	7,000
45. Lathe	2,800
46. Drill press	700
47. Grinder	300
48. Strainers	500
49. Sanitary tanks	1,000
50. Bilge, ballast, fire and fuel piping	12,000
51. Steam and exhaust piping	5,000
52. Water piping	7,000
53. Oil piping	3,400
54. Electric wiring	5,000
55. Floors, gratings, etc.	22,000
56. Uptakes and stack	25,000
57. Fresh water transfer pump	200
58. Lubricating oil service tanks	3,000
59. Tools, etc.	2,500
60. Ship's refrigeration	1,600
Total, pounds	822,995

Or 367.41 tons of 2,240 pounds each.

	Pounds.
Water in boilers	20,000
Water in other machinery	30,000
Total water in machinery	50,000

	Pounds per S.H.P.
Based on 6000 shaft horsepower, the dry weight is	137.2
Water, estimated at 50,000 pounds	8.3
Total net weight (6000 shaft horsepower)	145.5
Based on 7500 shaft horsepower, the dry weight is	109.7
Water, estimated at 50,000 pounds	6.7
Total wet weight (7500 shaft horsepower)	116.4

Based on 8500 shaft horsepower machinery modifications add 15 tons.

Based on 8500 shaft horsepower, the dry weight is 856,595 pounds.

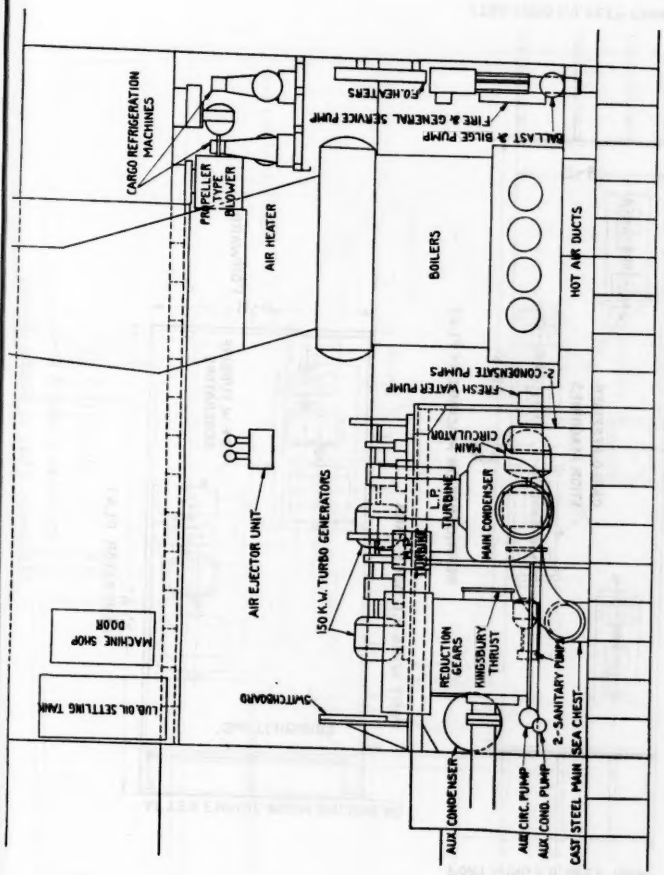


PLATE I.

STANDARD CARGO VESSEL.

Elevation Port Side Machinery Space.

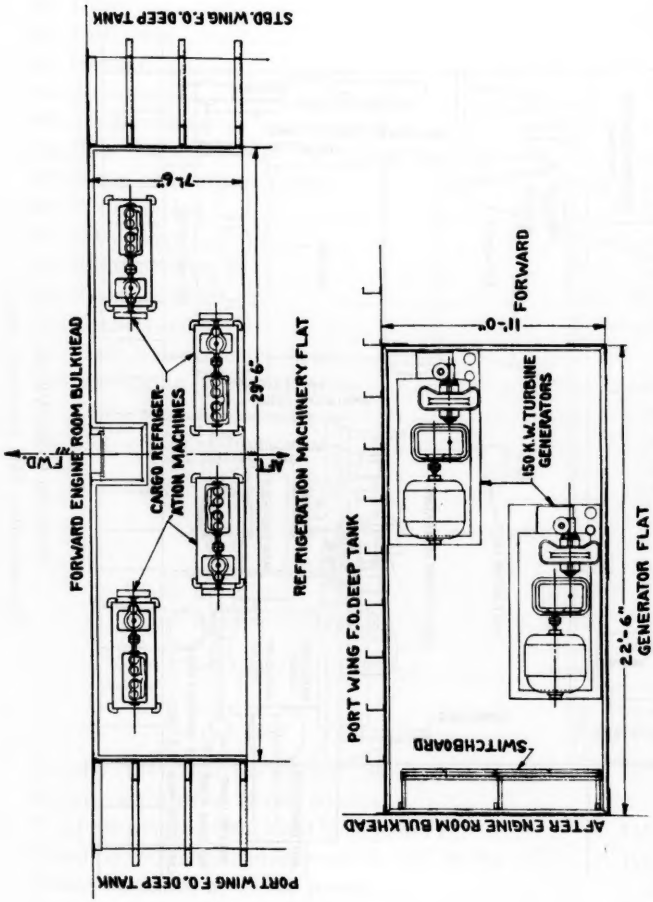


PLATE II.

STANDARD CARGO VESSEL.

Machinery Flats in Engine Room.

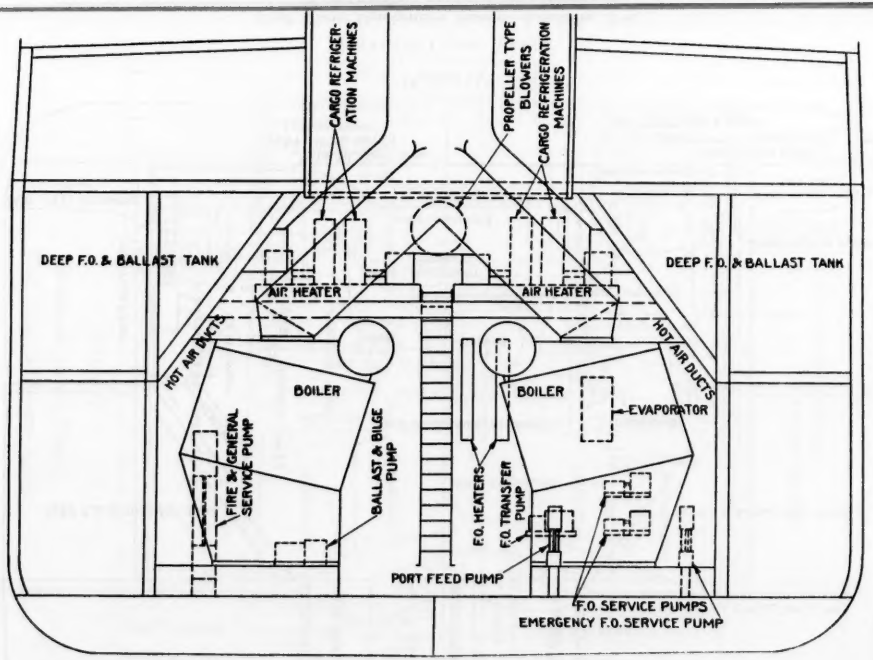


PLATE III.

STANDARD CARGO VESSEL.

End Elevation Machinery Space—Looking Forward.

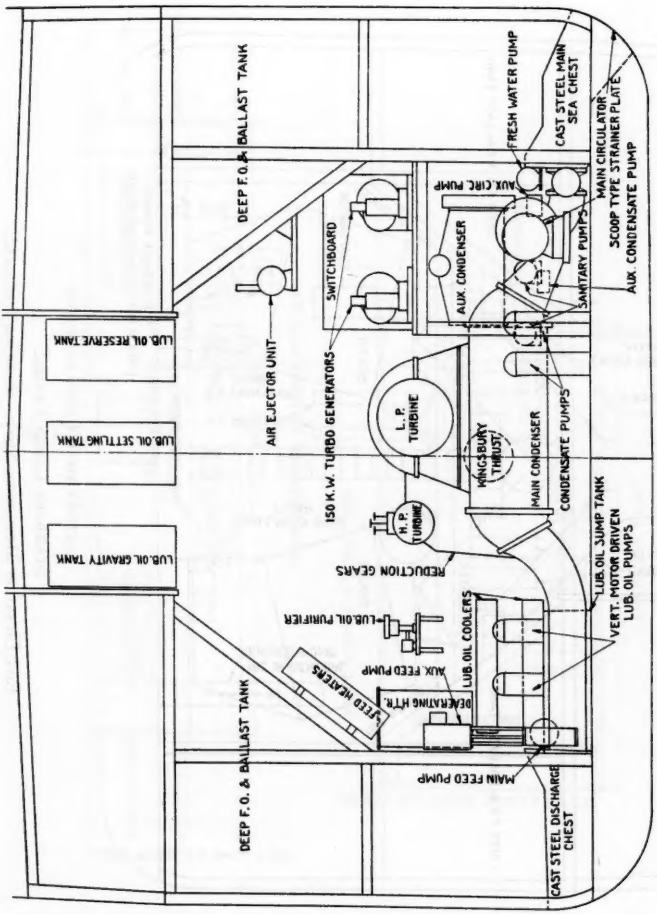


PLATE IV.

STANDARD CARGO VESSEL.

End View Machinery Space—Looking Aft.

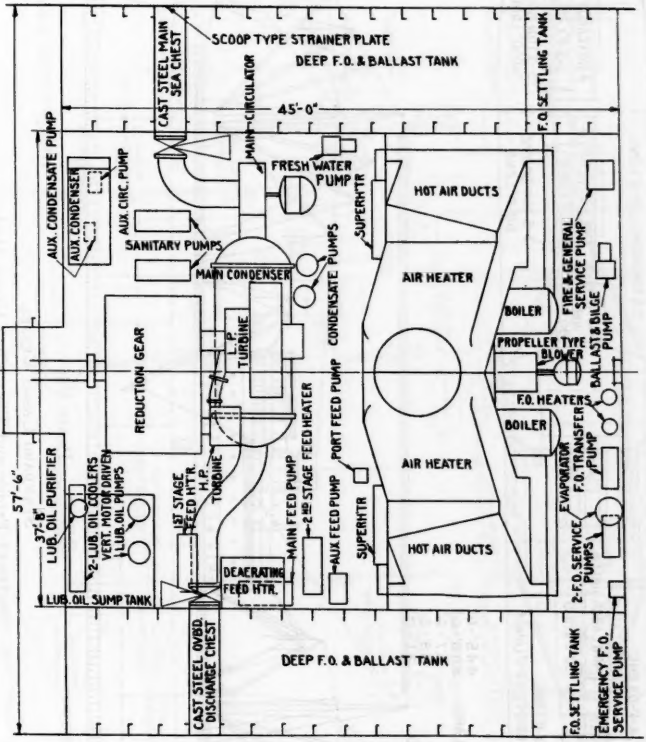


PLATE V.

STANDARD CARGO VESSEL.

Plan View Machinery Space.

STANDARD Cargo Vessel.
End View Machinery Space—Looking Aft.

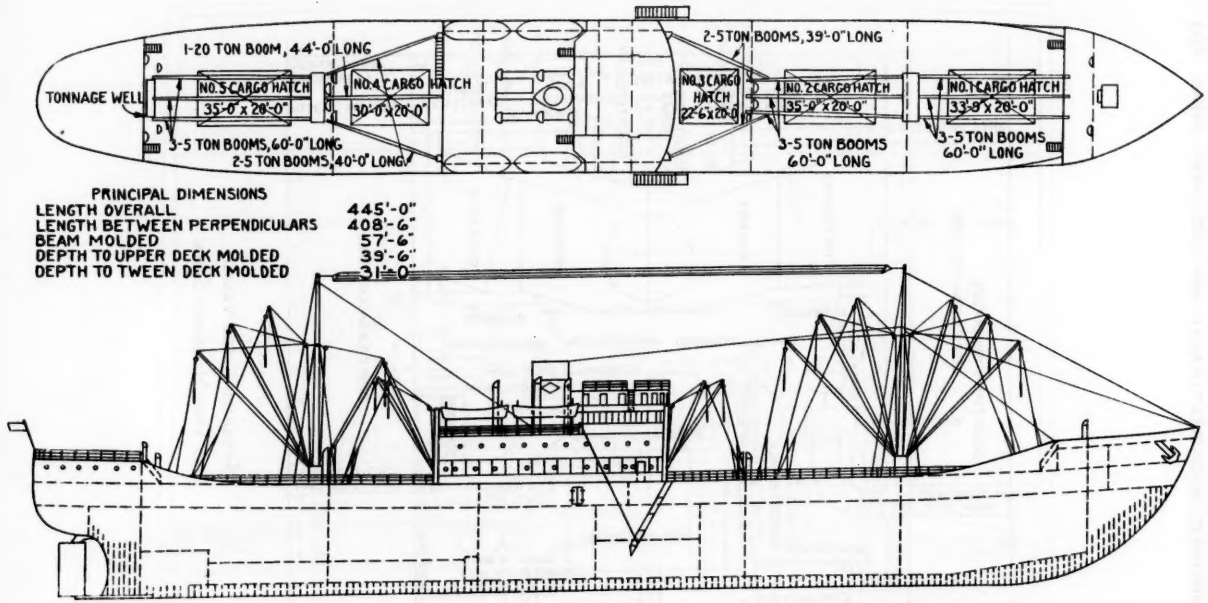
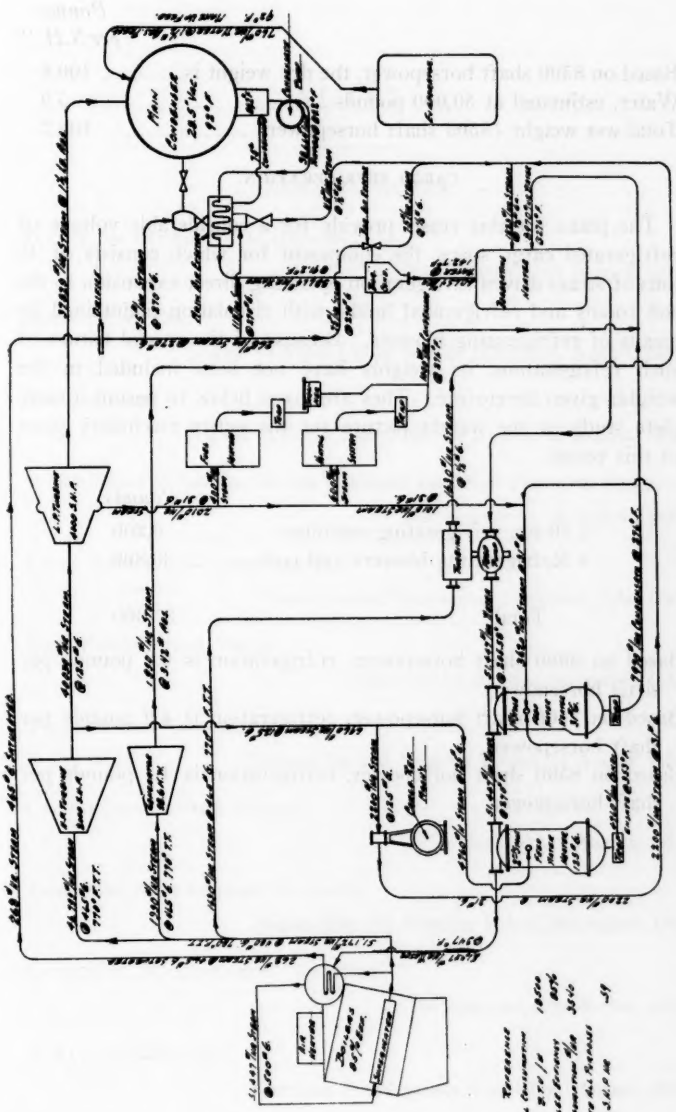


PLATE VI.

STANDARD CARGO VESSEL.

Outboard Profile and Plan View Upper Deck.



HEAT BALANCE, STANDARD CARGO SHIP, 6000 S.H.P. POWER PLANT.

	Pounds per S.H.P.
Based on 8500 shaft horsepower, the dry weight is	100.8
Water, estimated at 50,000 pounds	5.9
Total wet weight (8500 shaft horsepower)	106.7

CARGO REFRIGERATION.

The plans for this vessel provide for a considerable volume of refrigerated cargo space, the equipment for which consists of 40 tons of steam driven refrigeration operating direct expansion to the coil rooms and refrigerated holds, with circulation maintained by means of refrigerating blowers. Because of the special nature of such refrigeration, its weights have not been included in the weights given heretofore. They are given below to permit a complete study of the weight picture for the entire machinery plant of this vessel.

	Pounds.
4 10-ton refrigerating machines	6,200
4 Refrigerating blowers and coils	30,800
Total	37,000

Based on 6000 shaft horsepower, refrigeration is 6.2 pounds per shaft horsepower.

Based on 7500 shaft horsepower, refrigeration is 4.9 pounds per shaft horsepower.

Based on 8500 shaft horsepower, refrigeration is 4.4 pounds per shaft horsepower.

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LIGHT METALS AND THEIR ALLOYS.

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LAUNCH H. M. SUBMARINE "NARWHAL."

The Engineer, 6 September, 1935.

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American Foundrymen's Association, August, 1935.

JUSTICE FOR RETIRED NAVAL OFFICERS.

In 1896, a clause was inserted in the Naval Appropriation Act of that year, prohibiting retired naval officers from engaging in civilian employment where there existed contractural relationship with the Navy Department. While the reasons for this restrictive clause were obvious, as it related to the active list it had a most unfortunate effect upon officers on the retired list. Conditions have greatly changed as more and more of the national activity centers about the government. Many young naval officers who had not reached sufficiently high rank to enable them to receive substantial retirement pay, were compelled, when retired, to seek civilian connections to supplement their stipends. The restrictive clause of 1896, frequently stood in their way of obtaining employment and, as more and more of the large industrial organizations entered into contractural relations with the government, the field of opportunity for the retired naval officer who needed employment was further restricted. While inserted in the original appropriation bill of 1896 with the best of intentions, this clause worked great hardships on retired naval officers and efforts have been made for some time to modify its wording to permit these officers to utilize the knowledge and experience they acquired with the Navy.

The efforts made were not successful though year after year bills having to do with naval appropriations carried a section which sought to remedy the situation but was always stricken out before the bills were enacted into law.

This year, due to the splendid effort and co-operation of Senator Royal S. Copeland, chairman of the Senate Committee on Commerce, the discrimination contained in the clause of 1896 against retired naval and Marine Corps officers was lifted and the bill containing this remedial legislation has been passed and signed by the President.

The Naval Appropriation Bill of 1896 contained the following provision:

> "That hereafter no payment shall be made from the appropriations made by Congress to any officer in the Navy or Marine Corps on the active or retired list while such officer is employed, after June 30, 1897, by any person or company furnishing naval supplies or war material to the government; and such employment is hereby made unlawful after said date."

So far as this law applied to officers on the active list, it was obviously in the public interest, but in the case of retired officers, it not only worked injustice and hardship, but prevented the companies who did business with the government from utilizing the services of experienced men who understood the needs and requirements of the Navy and would have been in a position to render useful service to both his employers and the government.

This year, a bill was submitted to Congress entitled: "An Act to Regulate the strength and distribution of the line of the Navy, and for other purposes," which was officially known as H.R. 5599. This bill, which has been enacted into law, contained the following:

> Sec. 9. The last proviso of the appropriation "Pay of the Navy," contained in the Naval Appropriations Act for the fiscal year 1897, approved June 10, 1896 (29 Stat. 361), is hereby amended to read as follows: "*And provided further*, that hereafter no payment shall be made from appropriations made by Congress to any officer in the Navy or Marine Corps on the active list while such officer is employed * * * etc. * * * etc. * * *"

By removing this restriction from officers of the Navy on the retired list, an injustice has been remedied and retired officers may now engage in

civilian employment where their experience and familiarity with the needs of the Navy will be of mutual benefit to all concerned.

In our issue of January 15, 1935, I directed attention to this situation and discussed the possibilities with several naval officers on the retired list who were interested in changing this clause. I congratulate all concerned in this long continued effort to remedy an unfortunate situation.—"Marine Journal," 15 August, 1935.

JAPAN'S FUEL OIL.

By Ignatius Phayre.

The gravest problem of a military Power which is now clearly intent upon dominance in the most vast and populous of all the continents is, today, fuel oil. Japan produces little more than one-tenth of the petroleum and its products which she uses in normal times; in fact, the gross output of the Archipelago is less than half the peace-time needs of her navy alone. The larger grows her fleet and with it the air arms by sea and land, and the more mechanization is developed in her army, the greater becomes the Empire's dependence upon foreign supplies of fuel oil. So it is inevitable that Japan's sources of this commodity should be considered in relation to those controlled by Great Britain, the United States, Holland, and Russia; for if those sources were cut off in war-time it might well prove fatal to her.

For civilian purposes Japan's consumption of oil may be reckoned at 1,800,000 tons a year; it is officially so recorded. There are no such figures available for the navy's requirements, but the safest estimate of this is put at 400,000 tons. Here is a total provision of 2,200,000 tons, tending to increase largely year by year. To meet this demand, Japan herself can at present furnish only 242,000 tons. From Taiwan (Formosa) she may count upon another 35,000 tons, and thus far Manchukuo contributes some 25,000 tons. The total obtainable from sources under her own control is, then, 302,000 tons, or say, one-seventh of her peace-time demands.

Next comes a quota from the North end of Sakhalin Island, which is in Russian territory. A Japanese company operates these fields, leasing the wells from the Soviet Government and receiving from Tokyo a subsidy in aid. There still remains a balance of 1,700,000 tons a year to be imported from overseas. Of this, about 60 per cent, or say, 1,000,000 tons, is drawn from the United States. Most of this business is in the hands of the great Standard Oil Company, whose operations are world-wide; the remainder is drawn from the Dutch East Indies, mainly through the Asiatic Petroleum Company, which is run in equal parts by British and Dutch capital.

No exact data are to be had as to the amount of fuel oil which the Japanese have in storage for emergencies. Foreign concerns are understood to have at least three months' supply on hand locally; this might be as much as 400,000 tons and could, of course, be expropriated by the Government in any urgent crisis. Yet another 400,000 tons is supposed to be stored for the navy's exclusive use: this is one year's supply in normal times. A special proviso in the plan of Manchukuo's Government Monopoly decrees the storage of three years' ordinary supplies at Dairen; this is clearly intended for the imperial navy in any emergency.

Experts have estimated that in time of war the Japanese navy will consume 800,000 tons of oil a year, and that this would surely be found in stock. But as civilian demands could not be wholly eliminated, it is safe to say that on the outbreak of hostilities Japan's fleet could count upon a supply of at least six months' liquid fuel. Of course, war with a major naval Power might

be presumed to exceed this period, so the question of reliable stocks is one which must be faced.

In 1915 Japan's domestic sources of oil were speeded up to a record total of 2,600,000 *kokus* (1 *koku* = 48 gallons). From that peak it steadily declined. By 1926 it was only 1,450,000 *kokus*. Meanwhile the demand had increased enormously for steamships, aircraft (both civil and military), and automobile vehicles of all sorts from passenger cars to fighting tanks—to say nothing of navy requisitions; these last being rated as all-important in Japan's view of national defence in her narrow seas. As a result, by 1925 it was found necessary to import 2,170,000 *kokus* of fuel oil apart from the navy's 400,000 tons. And future policy had already begun to envisage a supply exceeding 1,250,000 tons a year, all of which was to be drawn from overseas. So it became imperative, as in Germany, to set applied chemists to work upon such oil shales as existed in the Archipelago, as well as in Japanese spheres of influence on the Asian mainland.

Beyond small deposits in Hokkaido, however, and in the Prefecture of Shimane, there was no oil-shale in sight. But at Fushun, in Manchuria, enormous deposits were available. Here the shale lay just above the coal-bed: within 500 feet of the surface, 1,200,000 tons were reported; at 1000 feet, 2,400,000,000 tons were estimated, and twice as much more at 2000 feet. The oil content was found to be from 9 to 10 per cent. An average of 5 per cent could be won from the shale by the Scottish dry-distillation process, as well as thirty-two pounds of sulphate of ammonia to each English ton. So that, all told, it was hoped that an oil-reserve of 120,000,000 tons might be counted on from this source. The cost of mining would be all but *nil* in these open-cut workings, and they were owned and operated by the South Manchuria Railway, which is now in Japanese hands.

Preliminary researches looked so promising that distillation-plant was installed on a large and costly scale. Moreover, coal-tar obtained by the low carbonization of coal was likewise essayed by Japan's technicians, who are second to none in this research work. An average of eighteen gallons of liquid fuel to a ton of coal was gained, and even up to twenty-six gallons at times. Other experiments included the hydrogenation of napthalene and the extraction of liquid fuel from water-gas and from animal and vegetable fats. The process-costs, however, ran high.

Meanwhile experts were sent to Russia, and later to Germany and England, to see what new lessons could be learned from other methods of synthesis. Thus at the Leningrad Industrial Institute a technical staff, headed by Professor Yakoviev, had found a way to extract petrol from peat, of which there were beds of 2,000,000,000 tons in the Leningrad area alone. This fuel, well tested in long motor-runs to Moscow and back, gave more power than the natural spirit. Engines ran more smoothly on it, and the cost was only half as much as that of petrol derived from petroleum. All these potential sources were painstakingly developed in Japan's laboratories.

Next, the oil processes of the I. G. Farbenindustrie, or German Dye Trust, were examined by Japan's chemists at the famous Leuna Works and other centers, where they were given every aid by that eminent administrator, the late Dr. Carl Duisberg. Here they studied the Bergius process of hydrogenising tar oils and brown coal, which had been undertaken with the same hopeful view of making the Reich independent of outside sources—yet in 1933 German oil imports were still valued at 122,000,000 marks, while synthetic petrol cost five times as much as liquid fuel bought abroad. Large subsidies were paid to prospectors in the oil fields of North Germany; then Berlin's gasworks put up plant to produce benzol as a by-product. In Münster (Westphalia), omnibuses were seen running regular services on "woodgas" at 7.50 marks a day, as against 31 marks for the usual petrol.

Lastly, the Japanese examined British experiments, especially the operation of an R.A.F. squadron run on petrol distilled from our own coal. This trial was begun in 1933; later on it was found possible to get nine Service squadrons flying entirely on fuel produced by the low-temperature carbonization of coal. But our Far Eastern visitors were also to learn that increased horsepower for a given size of engine had been mainly achieved by the use of spirit with a higher octane number.

It became apparent, however, that even the best of these substitutes could not equal the product of Nature's own laboratory. So, having explored many avenues which it was hoped would lead to effective self-sufficiency in fuel oil and lubricants, Japan's experts went home to report to their Government that, after all, this goal remained but the pious wish of inventive minds.

Meanwhile, the oil problem grew still more acute as Japan's commerce expanded and her fighting Services increased. At the talks in Downing Street last winter, both Admiral Suetsugu, the naval-statesman, and his colleague, Admiral Isoroku Yamamoto, hinted at an arrangement which might induce Japan to accept an inferior naval quota for another term: could Britain and the United States persuade the Dutch to cede or lease to them Borneo, with its large resources of oil? That such a proposal should have been even contemplated seems absurd; yet it shows how keenly contested is "The oil War," whose costly and strenuous *dessous* is so vividly set out in Anton Mohr's book of that name. The Japanese believe that British support alone guarantees Holland's tenure of the East Indies; and further that, since British capital largely owns and directs the Dutch oil-fields, a nod from Downing Street could ensure to Japan a reliable supply of her own, and one capable of large increase.

Failing this, Japan's naval chiefs together with the Ministries of Foreign Affairs and Industry in Tokyo devised yet another ingenious plan to provide an adequate oil-reserve—one that was to be promptly mandated by law in the face of energetic protest by the British and American Ambassadors. Each foreign vendor of oil products in the Japanese realm is thereby ordered to erect extra storage-tanks, and to maintain at their own cost a reserve equal to six months' sales. These large additional stocks are to be held under the *ægis* of Japan's armed forces, and are subject to requisition at a price to be arbitrarily fixed.

Simultaneously with this decree in Japan itself, the "puppet-Empire," as China continues to style it, of Manchukuo has declared a state monopoly in oil, and instructed the "Big Three" alien concerns within its borders to evaluate their properties and liquidate their former trading status. They are: the American Standard Oil; the Shell—known in the Far East as the "Asiatic Petroleum Company," and the Texaco. These sell more than half the oil and refined products used within the Japanese ambit of control. There was no evading what one of the harassed oil-directors described as "a monstrous proposal." The only alternative was to abandon markets in the Far East which had taken a generation to build up in credits; for even those of China could not survive the political and financial pressure which Tokyo could bring to bear upon Nanking and upon the remoter Provinces which are far beyond the sway of Chiang Kai-shek.

Such was the oil-move which Admiral Nobumasa Suetsugu, the late Commander-in-Chief, is said to have originated, and which the Tokyo press—especially the *Asahi* ("To-day"), which is the Prime Minister's own mouthpiece—lauded to the skies. But Admiral Suetsugu relies also upon Russia's oil, imported by the Matsukata Company. The head of this concern, a bold speculator who failed and lost his millions in middle age, set up again as a broker and jobber in Soviet oils when he was over seventy. And in the past three years Mr. Matsukata has amassed yet another fortune, having captured

nearly half the markets in Japan, and on the China coast as well, from our own and America interests, reducing the price of petrol in Pacific Asian ports from fifty cents an imperial gallon to nine cents. Matsukata has now secured a virtual monopoly in Russian oils from Korea to Siam, including China itself; and unlike the foreign importers, when ordered to hold stocks in reserve for his Government, this Japanese magnate received large subsidies to compensate him, as well as political favors and protection of substantial value. For in the last analysis, Japan seeks to keep the control of fuel oil in the national "family" until such time as this vital requisite can be drilled and won largely in territory of her own or else in one of her Asiatic spheres of influence, whether in Farther China or in the Philippine Archipelago, which seems destined to pass to her.

During the past year, the Service Chiefs in Tokyo have been putting out propaganda *à propos*. Of all the world's oil—about 200,000,000 tons in 1834—how negligible was Japan's direct contribution. On the other hand, her trans-Pacific rival had so much of it as to be swamped with rich "gushers," so many and free-flowing as to be an economic menace. As a fact, the present American output—so the Japanese "family" were reminded—is not less than 1,000,000,000 barrels of forty-two gallons each, with millions more derived from their own natural gas. Here was wealth of the American sub-soil worth over $700,000,000 a year. Here was oil literally cheaper than water: it had been offered at the fantastic figure of four cents a barrel! Not as a buyer, then, but as a keen seeker of markets for their deluge of "liquid power" did the United States today face the world, and especially Eastern Asia. No other nation owned oil sources at home so prodigally. They could account for 76 per cent of all the liquid fuel extant. So Japan must needs rely upon her rival for this supreme commodity! How could such a position continue, the Japanese people were asked. Three Western groups controlled the whole world's deposits of this precious stuff: Standard Oil, Royal Dutch Shell, and the Soviet Petroleum Trust. They had capital at command in hundreds of millions; they could, and did, scour the earth for fresh supplies, from Iraq and Persia to Venezuela. But where stood Japan in the vast strategy of this "oil war," which now covered the whole globe?

Her people are impressed by all these tendencious appeals. The head of their Government and his Minister of Marine—Admirals both—never tire of recalling the dictum of a well-known authority "over the way": "Naval strategy in another war," says Admiral Sims, U. S. N., "will be largely concerned with assuring ample and unfailing supplies of petroleum and its products, because this is now essential, not only for surface-craft of all types, but also for submarines and the fleet air-arm, which may yet have many surprises in store for the student of naval tactics."

The Japanese are also reminded by Admiral Mineo Osumi and General Senjuro Hayashi (of the Navy and Army Ministries) that Nature herself weighs down the scale against their island destinies. This refers to the incidence of earthquakes and their resulting fires which set the very sea and rivers aflame when the underground storage-tanks burst, as they did during the cataclysm of 1923, when millions of barrels of oil destroyed 100,000 citizens in a few hours of blazing horror.

It is clear, therefore, that Japan must view this matter of her oil-supplies as one of supreme importance. She will not feel secure in this respect until oil is located in sufficient bulk under her own control, and her geologists are still prospecting for it in likely areas. No political obstacle will be allowed to block this desideratum, and until it is attained the richest foreign sources must be pressed into service by drastic threats of business losses on a disastrous scale. Not only must the companies build more tanks in Japan

and lay in stocks far in excess of their normal needs, but they are also subject to quota restrictions on their retail sales, and these are so arranged as to favor the native merchants. "In case of emergency," all foreign stocks can be expropriated by the government at its own price.

Alien firms will only be licensed to operate for one year at a time, so as to ensure strict compliance with the new laws, and they must file estimates of their sales for several years in advance. Once that statement is accepted, all petroleum called for in it is bound to be imported "without regard to business conditions then prevailing."

It is thus that Japan is endeavoring to assure an adequate oil reserve for her fighting Services at the expense of British, American, and Dutch capital.

In Manchukuo, the treatment of foreign concerns is even more severe. The Tokyo Government owns half the shares of the South Manchuria Railway, which in turn holds 40 per cent of the Manchuria Oil Company; and of this firm, 80 per cent of the stock is in Japanese control. Now, it is to this company that the Emperor Kang-teh has given the monopoly of petroleum in his new realm. The head of this oil monopoly is Keizaburo Hashimoto; this magnate is the brother-in-law of General Takashi Hishikari, who is at once Tokyo's Ambassador to the "puppet-Empire" and Commander-in-Chief of Japan's Army in a new State of 35,000,000 inhabitants. Thus it will be seen that liquid fuel is at all costs to be safeguarded. The gaily-colored cans of the Standard Oil and Texas companies, as well as those of the Anglo-Dutch Shell group are to disappear, and every future receptacle must bear the seal of a monopoly under Japan's direct orders. Nor may any foreign firm even sell to the Monopoly itself until the entire output of the South Manchuria Railway's shale-oil plant and the new refinery at Dairen has been purchased. Any infringements of the laws entail penalties that range from confiscation of entire stocks to fines of 500-5000 yuan.

No wonder Sir Robert Clive and his Commercial Counsellor, Mr. Sansom, together with the U. S. Ambassador, Mr. Joseph C. Grew, and his Trade Adviser, Mr. E. L. Neville, all hurried with early protest to Koki Hirota, the Japanese Foreign Minister. But there could be no appeal from the *fait accompli;* for in this matter of fuel oil the Governments of Tokyo and Hsingking speak with one and the same voice—the voice of necessity.—"Journal of Royal United Service Institution," August, 1935.

GAS WARFARE
ITS POTENTIALITIES AND LIMITATIONS.

By "Respirator."

Great Britain, in company with most other nations, has signed an agreement not to use gas in war; but in view of the number of occasions when agreements and treaties entered into in time of peace have been violated in war, it is as well to appreciate what an infringement of the present engagement not to use gas would mean, and to what extent operations on land and sea might be assisted or interfered with by its employment. These potentialities and limitations are dealt with in the following article.—Editor.)

The Annals of War have nothing to compare with the record of "gas" between 1915 and 1918, as regards the rapidity and the scale of its technical and military development. The amazing expansion of its use as a weapon

of offence by our own Army has been most clearly and readably written by Major-General C. H. Foulkes,* who commanded the Special Brigade from its inception in 1915 until the end of the War. The story of the growth of chemical weapons is one of the greatest interest, told as it is from the point of view of the user; it is a pity that there is now small chance of the corresponding tales being told from the points of view of the technical producer and of the victims.

Gas! goes much beyond the limits of a mere Brigade history; the final "Summary" and "Conclusions" in particular are very provocative of thought as to the part which gas may play in any future Continental war. It is unlikely that any more comprehensive history of the chemical side of the Great War will ever now be written, since it is impossible to obtain any statistics of the results of our attacks from the "patient's" side. The German Government seem to have officially suppressed all details of the casualties caused by our attacks, and of any other direct or indirect effect which they may have had. Even the regimental histories of German formations only refer in the briefest and baldest terms to the fact that "a British gas attack took place on * * * at * * *"

In the absence of all confirmation from the German side, any estimate of casualties must be largely conjectural. The figures range from the ridiculously small 10,000 given by Dr. Hanslian in "Der Chemische Krieg," upwards; Major-General Foulkes gives reasons for multiplying that figure by twenty. Whatever the exact number may have been, there can be little doubt that the fear of our gas attacks ranked high amongst the things which most undermined the morale of the German troops.

Of quite as much interest to the student of psychology are the reactions of our own officers and men to the introduction of a new and untried weapon. This book tells of the dislike and distrust with which it was at first greeted, of the difficulties and obstructions with which it had to contend, down to the latter days, when no operation was complete without a large share being taken in it by gas, and when the efficiency both of our methods and of the Special Brigade were admitted by everyone. Also of interest to the same student is the mention of the way in which certain luckless German units were singled out for exceptional and intense treatment by gas whenever and wherever they appeared opposite our lines.

A full description is given of the production of the various weapons, from the first defective supplies of containers for cloud gas to the multiplication and perfection of different projectors and missles; of the changes in the kinds of gas used and the reasons for the changes; and of the elaboration of gas-tactics which took the enemy by surprise again and again. The book is also a welcome change from many others dealing with the Great War in that there is no word in it which can be construed as a personal attack upon anyone.

Development of the arts and crafts of the Special Brigade came to an abrupt end at the signing of the Armistice; but it is Major-General Foulkes' opinion that, in another few months of hostilities, the then impending deluge of mustard missiles over the German front might have had decisive results. It would certainly have made it easier to forecast the possible usages and dangers of gas in a future war and to make a balanced judgment of the part that it may yet play.

Before adventuring into the prophetic it may be as well to note briefly some of the features which helped the widespread use of gas by the British Armies.

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* "Gas!" The story of the Special Brigade. By Major-General C. H. Foulkes, C.B., C.M.G., D.S.O. (Blackwood.) 30s.

In the first place, to quote Major-General Foulkes himself, "there are always Bosches." We knew exactly where the enemy was and could be reasonably sure of finding him there, or thereabouts, at any particular time on a given date. Attacks could therefore be planned well beforehand and munitions assembled. Secondly, the weather, taken generally, was suitable for gas attacks from our side, and, to the discomfiture of the originators of chemical warfare, the wind set from our lines towards his more often than not. Thirdly, the stagnation of the front lines permitted the organization of a vast system of transport by rail, lorry, tramway, etc., so that gas munitions amounting to hundreds of tons in weight could be accumulated at short notice at almost any part of the front.

These factors all favored in an exceptional degree our use of chemical weapons; nor must it be overlooked that the operation of these weapons was in the hands of a truly "special" brigade of enthusiastic, and, latterly, highly skilled, personnel who lived, dreamed, and (sometimes literally) breathed gas.

Now it is an accepted axiom that any future European war will differ fundamentally from the last one in that it will be essentially mobile in character. The rules which applied in the past will, therefore, require alteration before they can be safely applied to the future, and allowance must also be made for developments in the interval. No commander of a mobile force will be able to count with certainty upon any of the three vitally important factors mentioned above; it may therefore be questioned whether he will care to embarrass his transport with, for instance, any quantity of material of such limited use as gas-cloud munitions. The word "limited" is used advisedly and with emphasis, for gas-clouds can only be used effectively in certain well-defined climatic conditions against a stationary enemy in more or less compact formation; limited further by the time and labor required to assemble them at the required point. It must be remembered that a little gas is little use; to be effective at all, either through its high density or through its long duration, a gas-cloud (or, indeed, any gas attack from the ground) makes a very heavy demand upon transport. Any serious addition to the existing complexities of supplying the bare essentials of a force in the field must be very surely justifiable.

On the other hand, gas-cloud munitions may with some certainty be expected to form part of the regular armament of all fixed defences, forts, etc. The installation of pipe-line systems, well outside the perimeter of the usual defences, as well as inside it, is quite feasible and their operation in an emergency would make no material extra call upon the garrison. Clouds from such a source could be of such concentration as to penetrate any existing type of respirator. Possession of the "weather-gauge" by an attacker would not carry with it immunity from the system once he was inside the pipe system; a resolute defender might well release a cloud to windward of himself and cause heavy casualties amongst the near-by attackers, whilst relying for his own safety upon the attenuation of the cloud over the intervening distance, or upon the gas-proofness of his own permanent structures.*

To a considerable extent gas-clouds in France gave way to gas-missile attacks owing partly to the scope which the latter give to variations in tactics, to their lesser dependence upon wind, and to the greater local concentrations of gas obtainable at their points of impact. For the same reasons, they offer advantages over gas-clouds in mobile warfare, but their limitations must be appreciated. Under certain not uncommon weather conditions, the

* It may be taken for granted that all fixed defensive works will approximate to 100 per cent gas-proofness, depending for their air supply upon some form of communal respirator or built-in oxygen apparatus.

dispersion of "true" gases is so rapid as to make them of little value however they may be used; under other conditions, vesicant liquids are also of very small use. Unless a mobile commander can foresee suitable conditions with some accuracy and can foretell which type of chemical will be most efficient under those conditions, or unless he can rely upon most unusually favorable transport arrangments, he would be unwise to encumber himself with any gas missiles at all. No all-purpose gas weapon exists; each type has its own special properties and none can perform the functions of high explosive shell.

The probable course will be for gas missiles to be available down the line at, say, two days' notice: available, that is, for an operation in the nature of a set-piece, but not for an impromptu battle. If, however, gas weapons are to be carried in the forefront of the advance, it will be a very difficult matter to decide what proportion of the limited transport is to be devoted to it, and what types of gas and missiles to select.* The decision may perhaps be influenced by the known temperament of the enemy, the efficiency of his respirator, or by conditions of climate and terrain.

MUSTARD GAS.

A force retiring upon its base will be more likely to have and to use gas, especially of the persistent types such as mustard.† It is clearly to the advantage of such a force to render the pursuit as difficult as possible by contaminating the ground which it vacates as heavily as it can; but the late War did not last long enough to provide any classic example of this use of mustard.

In 1917 and 1918 mustard caused 90 per cent of our gas casualties, and it was disseminated entirely by shell. The tactics adopted by the Germans involved the liberal plastering of certain areas with mustard, followed by infantry attacks along the "lanes" between the fouled zones. As these tactics were suspected on our side, we prepared to meet the attacks in just the places where they actually took place—which was not the result desired by the Germans.

It may or may not be an advantage of mustard that its casualty-producing results are delayed for some hours. If the gun-teams are prepared to suffer blisters on the morrow, it is of no value for the silencing of an inconvenient enemy battery; not only would gun fire not be stopped, but there would be no indication that any casualties whatever were being caused, which would be most discouraging. Where time is of no great consequence and the engagement is expected to last for some days, mustard might be the appropriate treatment, especially in the early stages; not solely to cause casualties, but also to make certain areas so dangerous for enemy occupation as to persuade him to "move along, please."

It may or may not be an advantage of mustard that the duration of its persistance is determined chiefly by the weather. It may at times be comforting to know that we can drench an area with mustard today, and yet be able to walk through it unscathed tomorrow. At other times we may find satisfaction in knowing that the area will not be inhabitable by anyone for days or weeks, without grave risk.

The value of mustard depends upon how the weather fits in with our plans; but, however that may be, mustard remains, *facile princeps*, the king of war chemicals: its insidious nature, the difficulty of detecting it, the yet

* In the late War the proportion of gas to H.E. used in an operation ranged from 20 per cent upwards. Major-General Foulkes himself seriously recommended using 100 per cent on occasion.

† Hereinafter "mustard" is to be taken as a general term for all vesicant liquids.

greater difficulty of locating and delimiting foul areas, keep it "top of the class" for both offensive and defensive purposes.

On the other hand, if the conditions and possibilities are not studied carefully, if mustard is used rightly but the plan otherwise fails, or if mustard is used wrongly in a plan which is otherwise right, then the user may be disastrously hoist with his own petard. The only "detector" which has yet been seen on a battle-field is the human nose; it is of very variable efficiency in different individuals, and in every case is unreliable in the fumes of battle. Failing any better detector, every man in every unit should be able to recognize at once the characteristic smells of his own and his allies' vesicants, as well as such aromas as the enemy may choose to add to his devil's broth; this is the first elementary step towards safety. The next is to ensure that every unit is fully informed of the areas within their neighborhood which it is intended to contaminate. Alternatively, the use of mustard must be confined to targets so remote that our troops cannot possibly occupy or traverse them. It may be worth pointing out that even the smell is no exact indication of danger, although it is wise always to treat it as such. A very considerable concentration of mustard vapor can be inhaled for many minutes without serious consequences, and the smell may be detectable a long way down-wind of the place where the liquid is lying in wait for the unwary. It may, in consequence, be quite safe to walk briskly through even a strong smell of mustard without any protection whatever; yet casualties may occur when no smell at all can be traced—for example, on the up-wind edge of a contaminated area where the smell may be only knee-high. On general principles, it is advisable to treat every smell of mustard as being potentially dangerous and as an instruction to put on the respirator and move away as far as duties permit.

Forces in retirement have everything to gain and nothing to lose by employing mustard in the largest possible quantities and by every available means. Mustard sprinkling may well play the part in the future which in former days was played by "laying waste the countryside" before an invader, so long, at least, as any soldier moves upon feet—his own or an animal's—and relies upon a respirator to save his (and its) lungs and eyes. There is hardly any limit to the number of ways of spreading mustard and improvised methods may be as effective as the drill-book ones.

As with other chemicals, mustard munitions of every kind may be expected as part of the equipment of all fixed defences, and of areas which are to be interdicted to the enemy. Pipe-line systems are feasible, or distribution may be done from carts, lorries, tanks, etc. The distribution would need renewal from time to time as evaporation took place, but rapid loss of potency may be checked by adulterating the mustard. A fully-mechanized invader might push through polluted areas without loss except perhaps later in the vehicle repair shops; unprotected infantry and animals would suffer very heavily. It is impracticable to cleanse any large area, even half a mile of roadway, from mustard; safe passage can only be obtained on wheels.

GAS BOMBS.

Turning now to the uses of gas from the air, the Great War again gives no guidance to the prophet, since neither side employed this method. Peace-time experiments on war-time scales are difficult and expensive to carry out, and conclusions so reached must be treated with reserve. Foreign nations have, however, for years been instructing their civil populations to expect such attacks, and our own Government is at last about to follow suit. It must be assumed, therefore, that gas from the air is a potentially useful weapon.

It may be doubted whether gas bombs of any type would be of much use against troops in the open. It is of no use to drop a bomb of lethal gas simply "near" its target; it must be on it or very close to windward of it; the determination what is "to windward" is, in itself, a problem for the pilot. Suppose the gas to have had time to expand from its original volume (*i.e.*, that of the bomb) until it covers an area 100 yards long. A gentle breeze of 5 miles per hour velocity will take that little cloud over any particular spot in much less than a minute, and it is only during that short period that there will be danger to personnel; moreover, this ignores the loss of concentration due to diffusion during the expansion, which much decreases what danger there may be. It follows that, to be effective, the bomb must be aimed with great accuracy in order that the local concentration may be high enough to penetrate the respirator, or a succession of bombs must be dropped throughout the whole time that it is desired to keep the enemy in his respirator. Both of these requirements present obvious difficulties in action, and it must also be said that (*a*) the effect is *very* local and transitory, (*b*) the puff is very clearly visible and avoidable, and (*c*) on a fine bright day the travel of the puff is more nearly vertical than horizontal.

Mustard bombs have a very limited area of "spatter" and for that reason are better suited for the contamination of ground than for direct action against personnel. For the same reason, more small bombs are to be preferred to a lesser number of large ones, because the area covered is greater; an increase in the area is generally more important than the degree of heaviness of the contamination. For fouling the line of march of infantry or mounted troops, mustard bombs might play a useful part, although, as will be shown later, there is a better way of accomplishing the same purpose. They might also be used wherever the enemy may be fairly sure to pass, *e.g.*, at fords, bridgeheads, or on ammunition dumps. Confronted with this obstacle, the alternatives are (1) to take a, possibly disadvantageous, detour, (2) to push through and accept casualties, or (3) to find some way of getting ferried through the danger zone.

SPRAY ATTACKS.

There remains to be considered that method called, cynically, by an American publicist "The Dew of Death"; even greater ignorance is displayed by civilian authors on this branch of the subject than on other aspects of the matter (*cf.* "Yell Hell" by Mr. Neverbeen Pickled). In essence, it is the ejection of vesicant substances from aeroplanes so that they fall to the ground as a fine rain; it is almost the equivalent of the old gas-cloud translated into terms of vesicants and with added horrors, as its presence is quite invisible and the respirator affords only slight protection. Without going into too much detail, it is sufficient to say that large quantities of mustard could thus be spread over very large areas of country, so that every unprotected man and animal within the limits of the shower would be a certain casualty.

Broadly speaking, there are few limitations to the manner in which this form of attack can be carried out, provided only that the drops of liquid do not evaporate or freeze on the way down; in the latter case they will still be dangerous when they thaw on the ground. If sprayed from a low altitude by "hedge-hopping" aircraft, the contaminated zone will be a long, narrow strip, very dangerous for massed troops. The strip expands in width as the height of release and the strength of the mean wind (from ground level up to that height) increase, until it becomes measurable in square miles rather than in square yards; this form of attack will be very effective against bivouac areas, bases, dumps, or against any bodies of troops who are not in immediate contact with the aeroplanes' friends. Each separate droplet is a

potential casualty-producer, and there is no room between them to escape contact with them. The aiming of the shower calls for no accuracy, providing the staff meteorologist can give the pilot the approximate strength and direction of the mean wind; this data may be obtained some distance from the target and still be sufficiently accurate.

From high altitudes or in strong winds, the aircraft may be far beyond the reach of A.A. guns emplaced in the area to be sprayed. The wind as felt by the soldier is no guide to the direction of the attack which varies with the height from which release is contemplated. As a culminating difficulty, the shower is invisible from start to finish—a point which is important enough to bear repetition.

The first indication that it has arrived will be the characteristic smell of the mustard; but by then it will be too late to take any precautionary measures whatever. The scientific ameliorative measures of bath and change of clothing and equipment are impracticable on active service. Every man and beast on whom the shower has fallen may be written off as a casualty within a few hours and it will be dangerous to touch any gear with unprotected hands until it has been cleaned.

How serious the danger from vapor may be—as distinct from contact with liquid drops—and how long the ground must be regarded as unsafe for occupation, depend upon the type and quantity of liquid used, the weather, and the nature of the surface of the ground. The two are interconnected, in that the more rapid the evaporation the greater the danger from vapor and the shorter the time that danger of either kind persists. They may range from the acute to the negligible, and from an hour to a matter of weeks.

It is obvious that mustard sprays are the greatest possible menace to armies in the field. The only defences seem to be (1) complete command of the air, or (2) that the troops shall be always under cover, which involves the mechanization of the whole force in enclosed vehicles fitted with some device for purifying the air inside, while covers must be kept over all gear in the open air. Or (3) the evolution of some form of military clothing which will be impervious to all kinds of vesicants and protect the whole body, coupled with a respirator in which all units can live, without detriment to their morale or their duties, for hours on end; even so all gear in the open must still be kept covered up.

Without doubt, nearly every nation has been busily engaged in the search for such clothing. Pictures of fire-brigades, ambulance men, etc., in Continental papers frequently depict them in hoods, capes or overalls which would be quite impracticable for a fighting man. America claims that by a special treatment the ordinary clothing can be made inpenetrable to mustard and Lewisite liquids; but this does not fully meet the case, since ventilation is a physical necessity and ventilation carries with it the danger from vapor; the claim must in any case be treated with reserve and caution, since it has not yet proved itself in the multitudinous strains of war.

Spray attacks are so simple to carry out, so rapid and economical in execution, so far-reaching in results, that it is difficult to see how any force could ever get anywhere in face of them, unless it could rely upon one of the three defences enumerated above. If it possesses (1), it has nothing to fear from gas attacks from the air; if (2), it has little to fear from gas, however used; if (3), it need only fear such high concentrations of gas as may penetrate the respirator.

It may be noticed that nothing has been said about gas of the "poisonous smoke" variety although it was rapidly coming to the fore at the end of the War. The reason for this omission is that all respirators are now proof against it; although its physiological effects are so delayed that a serious

and incapacitating dose may be inhaled unwittingly, yet the very manner of its production should give an observant enemy the suspicion that there was "something in the air"; and that should be sufficient to make him put on his respirator.

THE NAVAL ASPECT.

Gas has not hitherto been used against ships, nor is it likely to be in the future. Against men-of-war at sea, with freedom to maneuver and presenting erratic high-speed targets (as compared to the 4-knot foot soldier), the expenditure of gas for an effective cloud reaches prohibitive figures. Apart from this, there are the difficulties of locating, obtaining, and retaining the one correct position from which alone the attack can be launched to give a successful result, and of insuring that the enemy will steam into it, will not recognize it as gas, and will remain in it long enough to be affected without going to "gas alarm stations." It may be added that the greater proportion of many ships' companies are employed in structures which can be fairly easily and quickly made gas-tight, whilst to those who are necessarily exposed the respirator is by no means the same handicap that it is to their colleagues on shore.

Modern methods of harbor defence make it all but incredible that a gas-carrying enemy ship of any sort should be permitted to obtain the necessary close range from the harbor mouth without detection; if detected, the "element of surprise" has been lost to her and reasonably good gas-discipline will do the rest. Even should she be able to reach the desired spot, the elementary precaution of having gas-sentries posted up-wind of the ships will be sufficient to insure that there is plenty of time for the ships to take effective preventative measures.

Gas shells of any nature are out of place if used against a ship, when the only true and proper objective is the sinking of the ship, for gas shells sink nothing. For the same reason, gas bombs aimed at a ship would be much less effective than their equivalent in H.E.

Gas spray is, however, something which ships may well have to endure; but, given adequate organization and a realization of the problem, the results to ships should be more of an irritation than a disaster. Ships possess, or can possess, every requirement of the perfect gas shelter: cover for all, every desired store immediately available, and the ability to put such men as must be exposed into protective clothing without much loss of efficiency. Cleaning up the essential parts after the shower is over need not be a long process; a few casualties may crop up later, due to inadequate decontamination, but they are likely to be of small severity—one or two blisters on a sailor will be of much less importance than the same on a soldier, owing to the very different nature of their duties.

Dockyards and bases will, of course, offer very inviting targets for spray attacks; the measures to be taken to deal with them will be virtually the same as those applicable to any civil shore establishment.

If ships are again required to bombard shore targets, gas shell might be embarked *ad hoc*. The choice of gas would be governed by the rules of land, and not sea, warfare, with the caution that all fixed defences may be gas-proof until damaged by H.E. When the bombardment is a measure in itself or a prelude to other action at a later date, mustard would generally be more advantageous than other gases; but where there is to be a simultaneous or nearly-simultaneous landing, the more evanescent gases would probably find greater favor in the eyes of the landing party.—"Journal of the Royal United Service Institute," August, 1935.

WORLD TREND IS TOWARD GEARED TURBINES AND HIGH-PRESSURE STEAM.

In his paper entitled "Liner Development During the Past Fifty Years" * read recently before the North-East Coast Institution of Engineers and Shipbuilders, J. Denham Christie, vice-president of that organization, who is a noted British expert, finds that propelling machinery now most favored for large fast ships, is geared turbine using high-pressure superheated steam generated in water-tube boilers.

The past fifty years have witnessed many important developments in the design and construction of liners. There has been a continuous trend in the direction of building larger, faster ships. Improvements in propelling machinery and the use of oil fuel have enabled speeds to be attained which otherwise would not have been possible, and much has been done to add to safety and to the comfort and enjoyment of passengers. While the same general principles apply to the design of all liners, their size, speed and passenger arrangements have to be suitable for each particular trade, and lines may be grouped according to the main trade routes of the world. Of these the principal are the European lines across the North Atlantic to North America, the South Atlantic to South America and South Africa, and to the Far East, India, Australia and New Zealand, while across the Pacific are lines between North America and China, Japan, Australia and New Zealand.

1. Chief interest centers in the North Atlantic service with which the greatest developments in size and speed have been associated. Fifty years ago leading ships on the North Atlantic routes were the single screw steamers *Umbria* and *Etruria* of the Cunard Line, each of 519 feet overall length and propelled by compound reciprocating steam engines of 14,500 indicated horsepower. In 1888 the *Etruria* crossed from Liverpool to New York, 2855 nautical miles at an average speed of 19½ knots, the time taken being 6 days, 1 hour, 55 minutes. Today quadruple-screw ships over 1000 feet long, the French liner *Normandie* now making her maiden voyages or the Cunard White Star *Queen Mary* now under completion will cross the 3200 nautical miles from the English Channel to New York in 4½ days or less. The *Normandie* has already crossed at a speed of over 30 knots.

In the interval between the *Etruria* and the *Queen Mary* many notable Atlantic liners have been built; but in the short space at disposal here it is only possible to refer to those which have marked important stages of progress. The first twin-screw ships were the Inman Steamers *City of New York* and *City of Paris* completed in 1888 and having a record speed of 20.7 knots. These were followed in 1889 by the White Star *Teutonic* and *Majestic*. In 1893 the twin-screw Cunard ships *Lucania* and *Campania*, 600 feet long, 27,500 horsepower, brought up the speed record to 22 knots. In 1897 the German lines took up the running with the *Kaiser Wilhelm der Grosse*, followed by the *Kronprinz Wilhelm*, *Deutschland* and others. The White Star liner *Oceanic* completed in 1899, one of the best ships of her day, was not built to compete for speed, and the blue riband was held by the Germans with a speed of 23.5 knots until the advent of the *Lusitania* and *Mauretania* in 1906. The *Lusitania* and *Mauretania*, 787 feet long, quadruple-screw direct steam turbines 70,000 shaft horsepower, constituted an outstanding development in size, speed and comfort for passengers, and lowered all speed records. In 1909 the *Mauretania* with boilers coal-fired attained an average speed across the Atlantic of 26.06 knots and in 1929,

* This paper was read July 17, 1935, before the Institution, Newcastle-on-Tyne.

some years after being converted to burn oil fuel, she attained the remarkable average speed of 26.9 knots westward and 27.22 knots on the return voyage.

In 1928 after the *Mauretania* had held the speed record for 22 years, the Norddeutscher Lloyd Line brought out the quadruple-screw ships *Bremen* and *Europa*, 938 feet long and 100,000 shaft horsepower, having a speed of about 28 knots, and in 1933 the *Bremen* crossed from New York to Cherbourg at an average speed of 28.31 knots. In 1932 the Italian ships *Conte de Savoia* and *Rex* appeared, and in 1933 the latter with a speed of 28.9 knots for the westward crossing held the record until the advent of the *Normandie*. During the latter portion of the period under review the French Line, that is the Cie Generale Transatlantique, built the express liners *France, Paris, Ile de France*, and the giant *Normandie*, which vies with the *Queen Mary* in size and speed.

Reference so far has been confined to Atlantic liners built for speed. After the building of the *Lusitania* and *Mauretania* there was a period in which increase of size was favored rather than attainment of record speed. Typical vessels were the White Star *Olympic* and *Titanic*, the Cunard *Aquitania* and the three German-built ships, which became the *Berengaria, Majestic* and the *Leviathan*. The *Majestic* was the largest ship built up to the advent of the *Normandie* and *Queen Mary*.

Another type of Atlantic liner is the so-called intermediate class, comfortable ships of moderate speeds, 14 to 18 knots, economical to run. Of this type earlier ships were the Cunard *Ivernia, Caronia* and *Carmania*, and later the *Laconia* and *Aurania* classes. The White Star steamers *Adriatic, Baltic, Celtic*, and their recent motorships *Britannic* and *Georgic;* the Canadian Pacific *Duchess* class, the Hamburg American *Albert Ballin*, the French Line motorship *Lafayette* and steamer *Champlain*, the American ships *Manhattan* and *Washington*, the Swedish motorships *Gripsholm* and *Kungsholm*, the Dutch *Statendam*, and others.

Turning now to South America, ships for this service were limited in draught to 26 feet fresh water at Buenos Aires. The largest ship yet built was the French *L'Atlantique*, 744 feet long and 21 knots, which, unfortunately, was competely destroyed by fire two years ago. The Hamburg-South American Line have had a number of noteworthy ships, their latest being the *Cap Arcona*. The leading British line, R. M. S. P. Co., about ten years ago built two fine motorships for their South American trade, the *Asturias* and *Alcantara*, but the designed speed of these ships being too low to meet later competition they have been re-engined with steam engines of increased power and now run at a speed of about 18 knots. For an Italian line the *Guilio Cesare* was built on the Tyne, and lately there have been built in Italy the motorships *Saturnia, Vulcania* and *Augustus*, the latter with 25,000 brake horsepower being the largest-powered motor liner yet built. The Spanish Cia Transatlantica is represented by the Tyne-built *Reina Victoria Eugenia*, now *Argentina*, and other ships. An earlier ship for these owners, built on the Tyne nearly fifty years ago, was the *Alfonso XII*.

For South Africa, the Union Castle Line has long occupied the leading position and among their latest ships are the *Warwick Castle*, 675 feet long, 17 knots speed, and the *Llangibby Castle* of the intermediate type. These are motorships.

On the routes to India and Australia several well known British lines have maintained services for many years, the chief being the P. & O., British India, and Orient, also other well known names such as the Bibby, Blue Funnel, City, and Anchor Lines. The latest P. & O. ships are *Strathnaver* and *Strathaird*, 664 feet long, 22,500 tons gross, 21 knots speed, completed

in 1931-2, and the *Strathmore* now under completion. The *Viceroy of India*, the *Strathaird* and *Strathnaver* have electrical propulsion which is very suitable for the different speeds required on various stages of the run to India and Australia; but the latest ship, the *Strathmore*, has geared turbines as has the latest Orient liner *Orion*, which is a ship of the same size and speed as the *Strathmore*.

Besides British lines, the French Messageries Maritimes run fine ships to the East and so do Dutch and German and Italian companies. The new German ships *Scharnhorst*, *Potsdam* and *Gneisenau*, 652 feet long and 21 knots service speed, are notable examples of the latest developments. All have boilers of special types; two ships, 730 pounds pressure and one ship 1170 pounds; two have turbo-electric machinery, one geared turbines, two Maier form and one a bulbous bow. Their comparative results on service should be interesting and instructive.

For the trans-Pacific trade one of the chief lines is the Canadian Pacific with the *Empress of Japan* and *Empress of Canada* and other boats. The Union Company of New Zealand's chief ship quadruple-screw motorship *Aorangi*, built in 1925, and ships of the New Zealand Shipping Company and Shaw Savill Line also cross the Pacific. Of American lines there are the Dollar Line, *President Hoover* and *Coolidge* and the Matson Line *Mariposa*, *Monterey* and *Lurline*, ships 631 feet long, 20½ knots speed.

Having indicated by reference to actual ships the stage to which modern ocean-going passenger liners has developed, it is of interest to consider briefly some of the main technical features.

As regards proportions the tank testing of models has undoubtedly led to improved forms for liners as for other type of ships. For the *Lusitania* and *Mauretania* very complete tests were carried out with a number of models by the late Mr. R. E. Froude at Haslar, and in the case of the *Mauretania* these tests were supplemented on the Tyne by experiments with a model launch 47 feet 6 inches long constructed to the ship's lines and tested with various propellers. Judging by published figures, it does not appear that the latest ships are superior in form to the *Mauretania* in so far as minimum resistance and propulsive efficiency are concerned. The great advance has been in the weight and fuel consumption of propelling machinery.

Considerable interest has arisen during recent years in alternative forms for bow sections. The bulbous bow was adopted in the *Bremen*, *Europa* and others, while high claims are made for the Maier form of bow. Model experiments with these two forms of bows in comparison with normal bow lines are conflicting, and it would seem that it is more a question of wave-interference effects than shape of bow lines, and if the length is suitably adjusted to suit the form of bow, equal results may be possible with any of the alternatives. One interesting fact shown by experiments at the Hamburg Tank with a model of a large liner among waves was that a ship with a bulbous bow pitches forward into the seaway more than with the Maier or normal forms.

As already stated it is in connection with propelling machinery that the most striking advance has been made. Internal-combustion engines and turbo-electric propulsion each have their advocates and each have found considerable application, but the propelling machinery now most favored for large fast ships is geared turbines using high-pressure superheated steam generated in water-tube boilers. In the *Mauretania* with 80,000 shaft horsepower the weight of machinery was 9400 tons and the coal consumption about 1.35 pounds per shaft horsepower hour. In the *Bremen* with 120,000 shaft horsepower, the weight is 7763 tons and the consumption .685 tons of oil per shaft horse-

power; and her builders state that today with modern drum boilers of about 900 pounds pressure an installation of 180,000 shaft horsepower could be fitted with a weight of 7280 tons and consumption of .575 pound oil per horsepower, and occupying about 17½ per cent less strength than the present engines of the *Bremen*.

As regard structural arrangements, the tendency has been to have greatly increased superstructures, high 'tween decks and loftier deckhouses for the public rooms. In later ships the strength deck has been raised to a higher level which, apart from strength consideration, is of benefit from the point of view of longitudinal deflection. There has been considerable difference of opinion in regard to the provision of so-called expansion joints to relieve the lighter superstructure of longitudinal stress. It has been held, in particular by the registration societies, that it is preferable to have superstructures of increased scantling and no expansion joints. The disadvantage of this is that the increased top weight entailed militates against stability. An important consideration in connection with superstructures is that the transverse webs and pillaring should be suitably arranged to form, with the bulkheads of the main structure, efficient provision against racking when the ship is rolling in a seaway. In very fast ships where weight is an important consideration special steel has been used so that the upper works could be of reduced scantling. This was done in the *Lusitania* and *Mauretania* and also in recent ships of express type. The adoption of welding also saves weight and will doubtless be used to an increasing extent in future.

The loss of the *Titanic* in 1912 brought into great prominence the question of watertight subdivision and the numerous changes in subdivision since that date have been the bane of those concerned with liner design. However, in the International Convention for Safety of Ships at Sea, signed in 1929, some degree of finality has been reached on this matter, and a reasonable degree of safety provided.

In no direction does the passenger liner of today present a more marked contrast to the ship of fifty years ago than in the arrangements for the comfort, safety, and enjoyment of passengers, and a standard of luxury has been reached unthought of in 1885. The modern liner is indeed a floating hotel, equal if not superior to the best of hotels on shore, with spacious artistically decorated and handsomely furnished saloons and sitting-rooms and bedrooms, and with every imaginable fitting for the comfort and convenience of passengers by day and by night, and ample storerooms, wine cellars, kitchens and pantries having every modern appliance enable the tastes of the most fastidious to be catered for. For amusement and exercise there are concert rooms, theaters and ballrooms, gymnasium and swimming baths, games and play rooms and sports decks. A recent development is the introduction of tourist-class accommodation to cater for those who wish to travel for pleasure at moderate cost.

Electricity is being used for all purposes to a greater and greater extent. In the *Queen Mary*, for instance, there will be seven turbo-generators of a total output of 9100 Kw. And arrangements for ventilation and heating have reached a high standard of efficiency.

Safety of ship passengers and crew has had a very great deal of attention. One danger, that of fire, recently caused great losses in foreign liners and in some cases arose from insufficiently protected electrical fittings. This danger has now been carefully guarded against and there are very complete arrangements for the protection and suppression of fire. None the less the need for care and for proper fire discipline on board ship remains. Boats and appliances for getting them into the water are more effective than they

used to be. Systems for closing watertight doors from the captain's bridge have been perfected, and appliances such as submarine signalling, direction finders, gyroscopic compasses add to safety in navigating the ships, while wireless has done much to reduce risk and loss of life in case of serious disasters.

Notwithstanding the great advances that have been made during the last fifty years, there is still room for progress. If it could be brought about, complete absence of vibration and the lessening of pitching and rolling would add greatly to the comfort and enjoyment of those who travel in ships. A great deal has been done to minimize vibration which had become more serious with great increases in power and the advent of Diesel engines. But, although a good deal of experimental work has been done to reduce rolling, very little practical result has yet been achieved. For easy rolling it has become customary to design for moderate metacentric heights under service conditions, and one to two feet have proved satisfactory for large ships. In addition to bilge keels, various devices have been tried from time to time to lessen rolling, such as Frahm tanks and modifications of that system, which have been fitted in a number of ships. The most elaborate anti-rolling device yet tried is the gyroscope. Nearly thirty years ago Dr. Schlick, of Yarrow, Schlick and Tweedy fame, invented an anti-rolling gyroscope which Swan, Hunter, and Wigham Richardson, Ltd., endeavored to bring into use. They fitted it into three small ships and although the gyroscope could quite effectively reduce rolling, it was costly, heavy, and required a great deal of electric power and skilled attention, and eventually the gyroscopes were taken out of all three ships. The Sperry Company of New York, who were experimenting with gyroscopes, took them over and have since installed gyroscopes of their own design into a number of yachts and other ships. The installation of Sperry anti-rolling gyroscopes in the Italian liner *Conte de Savoia* is an enterprising step, but nothing has yet been published to show whether it has justified the great cost entailed.

Further increase in size for Trans-Atlantic liners seems unlikely. Instead, probably future efforts will be in the direction of attaining high speed and other required conditions with smaller dimensions. But on routes other than the Atlantic increase in size may still be found advantageous.

Improvement will doubtless continue to be made in machinery to enable power to be obtained with less and less weight and cost and fuel consumption.

This paper has only dealt with large passenger ships: there are, of course, many important passenger liners of moderate size, such, for instance, as those running on the Australian coast, of which typical recent ships are the twin-screw motorships *Manoora*, 482 feet, built on the Clyde, and the *Duntroon*, 472 feet, just completed on the Tyne, and a fine steamer 544 feet long, 23 knots, is now being built at Barrow for the Union Co. of New Zealand to trade between New Zealand and Australia. There are also numerous smaller passenger lines including cross-channel ships of high speed—ships which often present more difficult problems in design than vessels of larger size.

Besides, mention should be made of the large ocean-going cargo liners of good speed which carry a limited number of passengers, such as those running between this country and Australia and New Zealand. Among them are ships of the Shaw Savill, Blue Star and Commonwealth Dominion Line; a typical ship is the latter company's *Port Townsville*, a twin-screw motorship, 516 feet, 16 knots speed, just being completed on the Tyne.

In conclusion, my thanks are due to Mr. Bocler and to all those who have kindly supplied information which has been included in this paper.—"Marine Journal," August 15, 1935.

LIGHT METALS AND THEIR ALLOYS.

WILLIAM M. CORSE.

Time was when the alchemist, now fallen into disrepute, endeavored to transmute base metal to gold. This will-o'-the-wisp lured men to disappointment and ruin through many centuries, and the miracle never came to pass. Far-fetched as seems the alchemist's dream, it has been surpassed by the wizardry of the chemist and the metallurgist who between them have worked miracles in developing magnesium and aluminum and their alloys—the first from salt brine and the second from the alumina of the earth's crust. Known as the light metals of commerce today, these two elements and their alloys present an ever-increasing field of usefulness, particularly where weight saving is a factor.

ALUMINUM AND ITS ALLOYS.

Aluminum is the best known and most widely used of the two metals, though not the first discovered. It was first identified in 1722 by F. Hoffman, but his experimental work did little more than establish the fact that it was an individual substance, with characteristics peculiarly its own. Other chemists made other unsuccessful experiments; and it was not until 1809 that Sir Humphry Davy produced the first iron-aluminum alloy and named the new element "aluminum."

It remained for F. Wohler, a German, to be the first to produce aluminum in the metallic state in 1827. Almost another twenty years elapsed before H. St. Claire Deville, quite without intent, duplicated the Wohler experiments and produced aluminum about 1845. For several years he continued to experiment with chemical and electrical processes in an effort to segregate pure aluminum, with discouraging results. Potassium for the chemical processes cost some £17 per pound and was dangerous to use, while a primary battery provided the only electric current for the electrolytic process. Eventually, by substituting sodium for the too-expensive potassium, Deville produced metallic aluminum and shortly thereafter devised the method of abstracting aluminum from natural ores.

The first known object made of aluminum was a baby rattle which was presented to the infant Prince Imperial of France in 1855. Deville produced the aluminum from which it was made, and the metal, valued at $17 per ounce, was worth almost its weight in gold. In June of that year Deville announced before the French Academy that he hoped to place the aluminum industry on a firm basis soon, and he optimistically envisioned an "aluminum Age." It seemed to be right around the corner in 1855. But four years later the discoverer wrote in the concluding chapter of his "De l'Aluminum:" "I have tried to show that aluminum may become a useful metal, by studying with care its physical and chemical properties. As to the place it may occupy in our daily life, that will depend on the public's estimation of it and its commercial price. The introduction of a new metal into the usages of man's life is an operation of extreme difficulty." He little knew how prophetic were his words. Producers of new alloys, even to this day, will testify feelingly to their accuracy.

Aluminum at $17 per ounce remained a laboratory curiosity until the development of the electrolytic process, practically simultaneously, by P. T. L. Heroult in France and C. M. Hall in America about 1886. By means of this method, sometimes known as the Hall-Heroult process, aluminum was extracted from its natural ores at a marked reduction in price. From $17 an ounce in 1855, the price of aluminum fell to about $2 a pound in thousand-

pound lots by 1889, at which time Hall wrote to an associate in the Pittsburgh Reduction Company: "Nobody wants a thousand pounds of aluminum at even $2 per pound." Again the optimists who envisioned an aluminum age were doomed to diasappointment and delay.

Early Uses. There was one outstanding installation of the pure metal to which its producers pointed with pride. The cap on the Washington Monument, in the Nation's Capital, is a small pyramid of aluminum, 97.75 per cent pure, weighing 100 ounces, cast in 1884 by a Philadelphia metallurgist from metal of his own manufacture. This cap is of more than historical importance. Today, after exposure of half a century, it still reflects sunlight from its exposed surfaces. Recently when the monument was being repaired a group of outstanding metallurgists examined the aluminum cap and found it in excellent condition.

The chief merit of the new element was perhaps its weight-saving properties—aluminum is only about one-third the weight of common metals—and in the latter part of the nineteenth century the advantage of this quality gained recognition, though a clear conception of its full possibilities was not at once apparent.

The earliest use of aluminum was in kitchen utensils, popular because of their light weight, and pleasing appearance. They had the added advantage of high thermal conductivity as well as durability. Quantities of the new metal were consumed in producing them but the sponsors of aluminum had no notion of permitting it to be a Cinderella, consigned forever to kitchen duty and in the 1890's, it came out of the kitchen and went onto the roads.

Transportation. Aluminum began its work in the transportation field on the bicycle, when the heavy steel frames of the early models were superseded by aluminum alloys. Such was the modest beginning of aluminum's phenomenal rise in a field which today consumes by far the largest percentage of aluminum and its alloys.

The twentieth century rolled in on the wheels of the infant automobile industry, an industry that became the largest consumer of aluminum for several years. As early as 1904 motor bodies were being manufactured of sheet aluminum, particularly for pleasure cars. Eventually competition and reduced price eliminated sheet from bodies of these cars, but aluminum continued to be used for bodies of trucks and busses as weight saving became an increasingly vital factor in reducing cost of operation. The determining factor of reduced cost is the cost of haulage per ton-mile or passenger-mile, and the ultimate cost of aluminized units proved to be lower than those fabricated from the heavier metals.

By using aluminum alloys, 40 to 60 per cent of dead weight was eliminated, and this saving in nonproductive weight could be applied directly to the pay load without increasing the gross load. This was of tremendoums importance in the case of heavy-duty trucks that usually travel loaded to the maximum allowed by state legislation. When pay load was not essential, the decrease in dead weight resulted in improved schedule speeds, less wear on the chassis and tires, and lower fuel consumption.

The railroads and electric street railways grasped the full significance of weight reduction even quicker possibly because of the higher cost of propulsion energy in vehicles of this type. Shortly after the World War, it became apparent that the excessive weight of rolling stock had begun to affect not only motive power but operating cost, maintenance of equipment, permanent way, and other structures. The dilemma of the railroads is only too well known. It was but logical that transportation engineers should attempt to solve their problem by utilizing the new light alloys developed during the war, which so ably had demonstrated their suitability for construction of lighter-than-air craft.

It is a far cry from the lowly bicycles to the streamlined trains operating on our major railroads. Lack of space prevents the reproduction here of tables showing the chronological history of the development of aluminum utilization in the transportation field. Now the world has taken to the air, and though aircraft cannot hope to supersede the automobile, the railway train, or the tramcar but only supplement them, the aviation industry offers an increasing field for utilization of the light alloys.

On water craft as well, aluminum alloys are making for themselves a place, even though their uses are not so well known as in other forms of transportation. Aluminum castings are employed in Diesel engines. As a matter of fact, the largest aluminum castings ever produced were for the bed plates and crank cases of marine Diesel engines. One such casting weighed approximately 4 tons.

In small motor boat construction, aluminum alloys are coming more and more to the front. Aluminum masts have been popular since the *Enterprise*, in 1930, carried a light stick into the races to win against the fifth and last *Shamrock* in four straight heats. Other uses at once offered themselves and the *Diana II*, an English craft, was constructed almost entirely of aluminum, both as to structural parts and furnishings such as chairs, tables, cupboards, refrigerators, etc. A 65-foot patrol boat, built practically entirely of aluminum for the Royal Canadian Mounted Police, operates on the St. Lawrence River.

Structures. From the kitchen to the streamlined train was a long step, but aluminum and its alloys took another stride into the structural field. A glance around our large cities shows huge structures in which aluminum alloys have been used advantageously. In the Marshall Field Building in Chicago some 650,000 pound were used, principally in spandrels and windows. In the Empire State Building and the Rockefeller Center in New York large quantities of aluminum were utilized in grills, doors, trim, molding, windows, and spandrels. Aluminum structural parts have their place in the new United States Botanic Gardens in Washington where maintenance must be kept at a minimum and cleaning and painting cost kept down, especially on lofty portions which are difficult of access and subject to hot damp atmospheric conditions favorable to corrosion.

Aluminum was first used in structural parts of bridges in 1933. In that year the floor system of an important highway and electric street railway bridge in Pittsburgh was found to be in dangerous condition after 51 years of service. If money had been available, a new structure would probably have been erected, but in 1933 money was not easy to obtain. However, repairs had to be made. It was finally decided to replace the old floor system with structural aluminum, postponing the need of a new bridge for at least twenty-five years. The repairs cost $300,000, the new structure, had it been built, would have cost $1,250,000.

Present Production. Possibly no other metal can be obtained in so many diversified forms as aluminum. These include sand, die, and permanent mold castings; sheet, plate, and foil; bar, rod, and wire; structural shapes; tubing and moldings; forgings; screw machine products and rivets; and paint pigment. Its applications are legion, ranging from wrist watches to 25-ton dump trucks, and from screw machine products to railroad cars.

Aluminum began its commercial career in 1886 with Hall's discovery of the electrolytic process. In less than half a century it has achieved fifth place in the family of metals. In 1929 it reached a point, in volume produced, which copper reached only eighteen years earlier, and copper is a metal of antiquity that has been mined for more than five thousand years.

The tonnage of the four major metals—iron (and steel), copper, lead, and zinc—is considerably higher than the tonnage of aluminum produced each

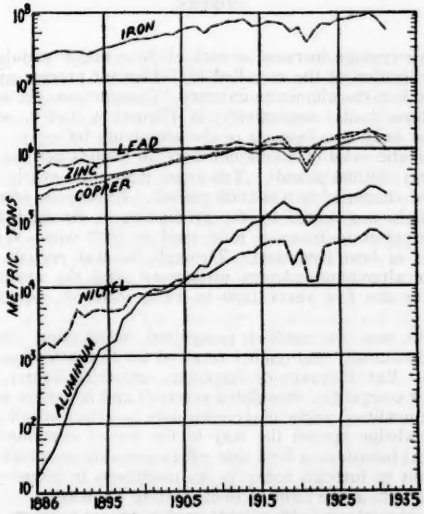

FIGURE 1. WORLD PRODUCTION OF ALUMINUM AND OTHER METALS SINCE 1886 IN METRIC TONS

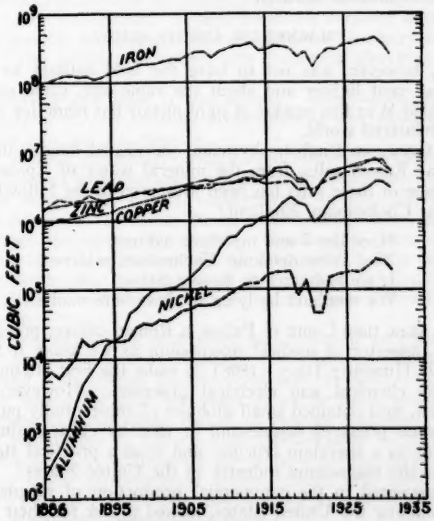

FIGURE 2. WORLD PRODUCTION OF ALUMINUM AND OTHER METALS SINCE 1886 IN CUBIC FEET

Calculated from the following specific gravities: iron, 7.7; lead, 11.34; zinc, 7.0; copper, 8.89; nickel, 8.7; aluminum, 2.71.

year, but the percentage increase of each of these major metals since the discovery and utilization of the so-called Hall-Heroult process gives an idea of the rapid growth of the aluminum industry. Comparisons are made on weight basis and volume basis, respectively, in Figures 1 and 2, which illustrate graphically the lusty development of the aluminum industry.

In 1886 domestic sales of aluminum were 50 pounds per day. In 1893 the yearly total was 198,000 pounds. Ten years later total yearly sales of ingot, sheet, and wire amounted to 6,462,000 pounds. Expansion proceeded then by leaps and bounds, augmented by the production of strong light alloys with properties equivalent to those of mild steel in 1912 when Wilm discovered the advantages of heat treatment. Through the war periods and the post-war years, the aluminum industry progressed until the average yearly domestic sales for the five years 1930 to 1934, inclusive, equaled 132,753,400 pounds.

Light weight was the earliest recognized outstanding characteristic of aluminum, and naturally that quality received the first attention of discoverers and producers. But discovery of magesium, one-third lighter, and therefore destined to be a competitor, stimulated research and invention which disclosed other valuable qualities, particularly resistance to attack of all kinds of acids. This new knowledge opened the way to the use of aluminum in equipment for the chemical industry—a field that offers amazing possibilities of development as difficult to forecast today as its usefulness in industry was to forecast fifty years ago, in the light of then-existing knowledge.

From domestic sales of 50 pounds a day to an average of 132,753,400 pounds a year in less than half a century is nothing less than a miracle. Reduction in price from $17 an ounce in 1855 to approximately 21 cents a pound in 1935 is another miracle.

MAGNESIUM AND ITS ALLOYS.

Aluminum, however, was not to have the field entirely to itself. Magnesium, 35 per cent lighter and about the same age, came out of oblivion. Since the World War this newest of light metals has made for itself a definite place in the industrial world.

Nehemiah Grew, an English physician, segregated magnesium compounds, now known as Epsom salts, from the mineral water of Epsom, England, in 1695. The fame of these salts has been preserved in the following epitaph on a tombstone at Cheltenham, England:

> Here lies I and my three dahters,
> Died from drinking Cheltenham waters.
> If we had stuck to Epsom Salts,
> We wouldn't be lying in these here vaults.

About that same time Count di Palma, a Roman citizen, prepared magnesia alba (white), ancestor of medical magnesium as we know it today. It remained for Sir Humphry Davy (1808) to make the first attempts to produce magnesium by chemical and electrical processes. However, Bussey, the French chemist, first obtained small globules of substantially pure magnesium in 1830. Bunsen prepared magnesium in 1852 by electrolyzing fused magnesium chloride in a porcelain crucible, and from a practical standpoint he is the founder of the magnesium industry in the United States.

Germany pioneered in the commercial production of magnesium, and all the world, including the United States, looked to her for their supply of the new light metal until the wartime embargo went into effect. The dire need of magnesium in national defense spurred research in Europe as well as the

United States, and by 1915 this country was successfully producing magnesium and its alloys. Today our production exceeds that of any other nation.

The General Electric Company was the first of the new producers. The Norton Laboratories and the Electric Reduction Company followed in the latter part of 1915. While the war-time demand continued, other new companies came into existence, such as the Aviation Materials Coporation, the American Magnesium Corporation, and the Dow Chemical Company. In 1917 five producers were operating. By 1920 only two remained—the American Magnesium Corporation and the Dow Chemical Company. In 1927 the American Magnesium Corporation ceased to manufacture ingot metal.

The new industry suffered many vicissitudes, and magnesium might have remained a fairly expensive curiosity but for the discovery, by the Dow Chemical Company, in 1916, of a successful method of extracting magnesium chloride from salt brine. This discovery revolutionized the industry, and 99.94 per cent pure magnesium is being manufactured today at a reasonable price in commercial quantities.

Aircraft. As lightness is the outstanding attribute of this newest of light metals and its alloys it was but natural they should make their debut in the transportation industry via aircraft where light weight is of supreme importance.

Magnesium was useful in aircraft; but as aluminum left the kitchen and the roads for the air, so magnesium left the air for far horizons on that famous expedition in 1934 when the National Geographic Society and the United States Army Air Corps ascended into the stratosphere, in the gigantic balloon known as the *Explorer I.*

The equipment for that flight weighed about a ton. In order to carry this weight to the desired altitude of 75,000 feet, a baloon of 3,000,000 cubic feet capacity had to be constructed. It was necessary to keep weight at a minimum and the gondola was constructed of Dowmetal,* industry's lightest structural metal. The gondola, a sphere 100 inches in diameter, weighed 700 pounds.

The 1934 stratosphere flight is now history. Even as this article is being written, the *Explorer II* is awaiting proper atmospheric conditions for a second expedition into the stratosphere.

In aircraft engines particularly, magnesium alloys have been used to good advantage. Aircraft manufacturers are utilizing them for crank-case covers, breather caps, starter-hole covers, supercharger scrolls, carburetor air-inlet pipes, intake manifolds, accessory cases, main bearing caps, and various unstressed castings throughout the engine. Crank cases, cam shafts, and accessory drives have also been made of magnesium alloys with successful results. The latter two, by eliminating bronze bushings, have reduced both cost and weight—no small matter where every ounce of dead weight eliminated is a virtue.

Roy Minor flew his *Miss Los Angeles,* equipped with an engine using magnesium alloy parts, in the 1934 National Air Races at Cleveland and won. Planes equipped with similar engines have won, in open competition in the United States during the past few years, more air races and prizes for racing competitions than all other makes of engines combined. Undoubtedly light weight contributed to the excellent performance of these planes. In addition to engine parts magnesium alloys have proved suitable for landing wheels, brake shoes, miscellaneous control parts, and instruments. Nonstressed parts such as cabin lining, baggage compartments, chairs, and wing covering are consuming quantities of sheet.

* Dowmetal is a magnesium alloy manufactured by the Dow Chemical Company, Midland, Mich.

In Europe forged magnesium alloys are used commercially, but are still in the experimental stage in the United States. With improvement of forging technic it is believed that forged magnesium alloy propellers will become standard aircraft equipment in this country in a short time. Supercharger impellers and bearing caps are now being forged.

The alloys are available in an ever-widening variety of cast and wrought forms such as sand castings, die castings, forgings, structural shapes, screw machine stock, tubing, plate, sheet, strip, wire, and rod.

Other Uses. Magnesium alloys are being used in construction of trucks, trailers, and busses. The same basic advantages are found in the substitution of magnesium alloys for those of aluminum, as were found in the substitution of aluminum alloys for those of older metals. By further lightening of structural parts, the pay load can be increased and operating costs decreased. One manufacturer has seen the handwriting on the wall and has already built over one hundred commercial truck bodies and trailers. From present indications, this field will expand rapidly. A large passenger bus manufacturer is today experimenting with magnesium alloy castings, sheet, plate, tubes, and other parts, with the definite object of cutting dead weight to a minimum.

The portable tool field offers another outlet for magnesium alloys. Tools on which these castings are used include electric and pneumatic drills, grinders, sanders, prospecting drills, mine drills, and saws. Service extending over several years indicates that magnesium alloy castings withstand all normal service conditions. Magnesium alloy castings are also being used for motor housings, gear housings, covers, and handles.

As magnesium followed aluminum in the transportation field and partially superseded it because of that magic quality lightness, so too we find it following into other industries and other fields.

In the home, magnesium alloy frames for vacuum cleaners, ironers, etc., bid fair to take heavy-duty work from the shoulders of the housewife. In the foundry other types of the alloys are used for snap flasks, patterns, core boxes, rolled pattern plates, and core-setting gages, resulting in increased production because of elimination of much manual labor. In offices these alloys have lightened the frames of business machines and of furniture. In fact, where aluminum alloys have pioneered, magnesium alloys can be used to advantage in many instances (with the exception of the chemical industry), particularly where reduction in weight is a primary object.

Magnesium alloys have proved their value in parts for printing presses, bread slicers, packaging machinery; for cigarette, canning, and bottling machinery; and for conveying machinery of all kinds. They have been used successfully in the construction of hydraulic couplers, blowers, and fans. Electric motors are utilizing them for ventilating fans. In fact, wherever light weight contributes to easy and economical operation of automatic high-speed machinery, these newest of light alloys are indicated, particularly in reciprocating and revolving parts where it is necessary to keep inertia at a minimum.

One large Geneva gear cam used for manufacturing electric light bulb cases was formerly equipped with a cast-iron cam weighing 160 pounds. This cam was replaced by one of magnesium alloy weighing 40 pounds. As this Geneva gear must start and stop for indexing many times a minute, the lighter weight part was extremely advantageous since it permitted the machine to be speeded up without excessive vibration and shock.

Where high-impact resistance is required, magnesium alloys are particularly useful. Fluted safety blocks of this material, 18 inches high and 10 inches in diameter, capable of carrying a static load of 620,000 pounds were in-

stalled in presses by one large automobile concern. When the presses fell, owing to the accidental tripping of a switch, the alloy blocks remained intact, whereas, in a similar accident where green oak blocks were in use, the blocks were demolished and the workers beneath the press injured.

Present Production. Magnesium is industry's lightest structural metal, and this quality distinguishes it from all other engineering metals. But it has other valuable qualities that will extend its usefulness rapidly. Among them are machinability (it machines as easily as wood) and resistance to the attack of alkalies as well as many organic chemicals, including hydrocarbons, some aldehydes, alcohols, phenols, and most oils. It does not then take much imagination to envision the wide field of usefulness of a metal with such qualities.

In the early stages of our American industry, a 120-ampere cell required a day to produce a single pound of pure magnesium, and in 1920 one producer considered that an inventory of 20,000 pounds was sufficient for a year's requirement. Today improved individual units, in certain stages of the dehydration process, can produce raw material equivalent to 20,000 pounds of metal per day.

Cost is a great factor in the usefulness of any metal, and high cost of magnesium was a drawback in the early days of its development. In 1915 ingot magnesium sold for $5 per pound. Seventeen years later the cost had been cut to approximately 30 cents per pound by improved production methods and new inventions. At this price it compares favorably with other metals already well established for industrial purposes.

Increase in rate of production from one pound to 20,000 pounds of metal per day per unit is a miracle. Reduction in price from $5 per pound in 1915 to 30 cents per pound less than two decades later is another miracle.

CONCLUSIONS

Light weight is the outstanding characteristic of both aluminum and magnesium, with the odds in favor of magnesium. All other things being equal, the two are competitors in the industrial field. But each is endowed with qualities peculiar to itself, and the erstwhile antagonists complement each other in the field of chemical industries. Aluminum and its alloys are indicated where acid resistance is a factor. Magnesium and its alloys are called upon for equipment to resist the alkalies, many types of organic chemicals, and most oils. To attempt to substitute one for the other is fatal in the chemical industry.

Expansion of the field of usefulness of aluminum from a baby rattle presented as recently as 1855 to the Prince Imperial of a now obsolete monarchy, to the magnificent structures that span our skylines, to airplanes, ocean vessels, bridges, and streamlined trains that utilize this metal today, is an achievement worthy of Aladdin and his wonderful lamp.

It is a far cry from the magnesium compounds isolated in 1695 by Nehemiah Grew, to the high-strength, light-weight alloys of magnesium—industry's lightest structural metal; and the important developments of today and tomorrow lie in the utilization of the ultralight-weight magnesium alloys in the structural field.

The surest guide to future possibilities is the past, and the achievements of aluminum and magnesium, since their modest industrial beginnings, less than a century ago, would indicate that the future holds unfathomed possibilities for development of both metals in the fields to which they are adapted.—"Industrial and Engineering Chemistry," Vol. 27, Page 745, July, 1935.

HARD-FACING STEAM VALVES.

An Economical Method of Multiplying the Useful Life of Valves in High Pressure Steam Service.

More and more power plants are now using Haynes Stellite trim on valves handling high-pressure, high-temperature steam, gas and oil. The hard-facing alloy is applied to the seats and disks of all types of gate and globe valves by means of the oxy-acetylene process. Invariably the results are six to ten times longer service and fewer shutdowns for repair and replacement. This non-ferrous alloy trim assures tight, leak-proof dependable service because it will not seize or gall and because it resists both erosion and corrosion to a remarkable degree. A few typical examples will serve to illustrate the savings this type of construction makes possible on valves operating under particularly severe conditions.

Several years ago, when the use of the non-ferrous alloy as a seating material for high-temperature, high-pressure steam service was still in its experimental stages, a large utility company decided to test Haynes Stellited gate valves. These valves, up to 10 inches in diameter, handled steam at exceptionally high temperatures and pressures which caused leakage to develop in a comparatively short time.

Their decision to hard-face these valves had several objectives: to insure longer life; to lessen costly shutdowns; and also to reduce the unit cost of keeping the valves tight. First the gates and rings were machined to provide clean surfaces for the hard-facing alloy. The hard-facing welding rod was then flowed onto these surfaces by means of an oxy-acetylene flame, and the surfaces were ground to the desired finish.

The valves were hard-faced in this manner at a cost slightly more than the cost of new seats and disks. However, the Haynes Stellited valves have now been in continuous service for more than three years as compared with a former life of less than one year, and, from present indications, they are expected to give efficient service for many more years to come.

A mid-Western manufacturer of locomotive specialities reports that the use of hard-faced valves for locomotive service has proved especially satisfactory. One 1½-inch valve having two hard-surfaced disk seats and used for blow-off service has been in constant use for over two years, during which time the hard-faced seats have shown no wear, and the valve has remained tight. The non-ferrous alloy is applied in a machined groove and then ground and lapped to form the seating surfaces. Many other valves in service on locomotives have likewise given practically maintenance-free service.

MARINE SERVICE.

One of the large ocean-going steamships is equipped with a 3⅛-inch poppet-type valve for controlling the flow of steam through the main whistle. This valve operates at 375-pound pressure and 590 degrees F. and is opened and closed by a piston arrangement controlled by an auxiliary valve. When the valve closes, the disk pounds down heavily on the seat. The result was that a deep groove was formed on the seating surface of the disk.

Prior to the adoption of hard-faced seating surfaces, it was necessary to remove the valve every two weeks for refinishing the disk and seat. Besides the actual time required to reseat the surfaces, it took 1 hour to remove the valve from the line and 1 hour to install it again. In addition, the valve would begin to leak again after but two or three days' service, resulting in a constant loss of steam.

It was decided to protect the seating surfaces with a welded-on layer of Haynes Stellite. The alloy was deposited by means of the oxy-acetylene blowpipe to a depth of approximately ⅛ inch, the welding operation requiring about 1 hour for both seat and disk. The hard-facing deposit was then ground to an accuracy of 0.0005 inch and the disk was finally lapped to the seat with powdered pumice.

The hard-faced whistle valve was installed almost a year ago. Three months later the valve was removed from the line for inspection and the hard-faced seating surfaces were in as good condition as when installed. At present the valve is in excellent condition and has required no attention whatsoever. It has already saved eighteen costly shutdowns.

RECOMMENDED USES.

Numerous other installations also are proving the value of this alloy trim. One plant reports hard-faced valves have been in service for two years without leaking as compared to a life of only a few months for valves made of other materials. At another plant, a hard-faced seat ring and disk showed absolutely no indication of scoring or wire drawing after 14 months' service on a 460-pound super-heater line and the valve was as tight as when installed. Still another plant which operates its boilers at 1200 pounds per square inch reports that the life of valves on its boiler feed pumps has been increased from 500 hours to more than 5000 hours by hard-facing. Such results as these more than justify the use of hard-facing as a means of prolonging valve life.

Non-ferrous alloy trim has been found to prolong the useful life of all types of gate, globe, angle, check, needle, safety non-return, blow-off and regulating valves where operating conditions demand that a seat and disk material be free from seizing and galling and also be corrosion resistant. The higher the temperature and pressure, the more valuable is this material. The alloy has been found particularly advantageous for valves handling hot, high-sulphur crudes containing free SO_2 and SO_3. The use of hard-facing is indicated where operating conditions are especially severe, where seats and disks wear excessively, requiring frequent repair, and where valves are not readily accessible.

Depending on the type of service, hard-faced valves last six to ten times longer, thereby requiring fewer shutdowns for costly repairs and replacements. This is particularly important where valves are not readily accessible and where even temporary shutdown means partial paralysis of the steam transmission system.

Hard-faced valves remain tight and insure leak-proof, dependable performance. Power losses are reduced to a minimum, resulting in a general increase in operating efficiency. When properly deposited on the base metal, Haynes Stellite is not subject to warpage or distortion by virtue of repeated heating and cooling. In addition, the low coefficient of friction of this alloy is especially valuable in certain types of valve construction where the disk travels in a rotating motion over the face of the seat.

PHYSICAL CHARACTERISTICS.

It might be well to review quickly the reasons why non-ferrous, cobalt-chromium-tungsten alloy has proved so successful as a seating material for high-temperature, high-pressure steam valves. Briefly, these are, (1) it

maintains its strength and hardness at elevated temperatures, (2) it is extremely abrasion-resistant and (3) it is corrosion-resistant.

Physically, one of the outstanding characteristics of this alloy is its high degree of "red-hardness," or the ability to retain its hardness even through the red-heat range. At 750 degrees F. this material is practically as hard as at room temperature and at temperatures above 1100 degrees F., it is harder than any other known hard-facing alloy. Its strength and hardness at elevated temperatures account for its resistance to wire drawing and to the erosive effect caused by the flow of steam.

This non-ferrous alloy is one of the most abrasion-resistant metals known to industry, and this characteristic is directly due to its red-hardness and low coefficient of friction. It takes a high polish and is so smooth that it makes an excellent burnishing tool because it does not pick up other metals. Abrasion-resistance, smoothness and low coefficient of friction are the reasons for the non-scoring characteristics of hard-faced seats and disks.

Seats and disks treated with this type of surfacing material are resistant to all forms of corrosion that might be encountered in steam service. They are also resistant to high sulphur crudes and other corrosive materials. In general, it may be said that non-ferrous hard-facing alloy has the same corrosion-resistant properties as the chromium-iron alloys, only to a greater degree. In addition, the alloy does not scale or oxidize when heated.—"Pacific Marine Review," September, 1935.

THE SCOUTING CRUISER.

One of the Greatest Problems of the British Naval Designer for the Last 70 Years.

(From a Naval Correspondent.)

After carrying out successful official trials, H.M.S. *Galatea*, a cruiser belonging to the 1932 British naval construction program, has been delivered to the Admiralty by her builders, Scotts' Shipbuilding & Engineering Co., Ltd., Greenock.

This is one of the new cruisers of the *Arethusa* type, and the vessels have been criticized rather severely on account of their small size and weakness. In designing them, the Admiralty officials have been faced with a very difficult task and more allowance should be made for this difficulty than has so far been given.

The *Arethusa* has a displacement of 5200 tons, a nominal speed of 32¼ knots, an armament of six 6-inch and four 4-inch guns, anti-aircraft pieces and six torpedo tubes.

It is not easy to find foreign ships of similar size with which comparison can fairly be made, as the requirements of foreign navies are not the same as the British, but the second *Condottieri* class in the Italian Navy, dating from 1931, has a displacement of just over 5000 tons, an armament of eight 6-inch and six 3.9-inch guns with four torpedo tubes and a nominal speed of 37 knots, which has been greatly exceeded on trial. The German *Leipzig* of 1929 is rather larger, 6000 tons, and mounts nine 6-inch guns and four 3.4's in addition to twelve torpedo tubes, while her nominal speed is 32 knots. In the Japanese Navy it is necessary to go back to 1923 to the *Jintsu* class, 5195 tons, with an armament of seven 5.5-inch guns, two 3-inch guns and eight torpedo tubes, the nominal speed being 33 knots.

INTERNATIONAL LIMITATION.

On paper, therefore, it would appear that the *Arethusa* is far behind her foreign rivals even of considerable age, but it must be remembered that she is designed under the international agreement which limits our cruiser quota, and that therefore the ships of the type had to be small in order to secure the necessary number. Small size, in fact, may be a distinct advantage for many of the tasks which are likely to fall to the lot of the *Arethusa* class, particularly scouting and convoying.

Every war since the beginning of organized naval warfare has seen a demand for small craft in its early days, and it is obviously difficult for the shipyards to supply this inflated demand at short notice. The British Admiralty may, therefore, prove to be fully justified in building these ships of very moderate size and power beforehand, so that their plans are all ready, and their abilities and faults fully realized, before ships of approximately their type have to be built in numbers.

The scouting cruiser has been one of the greatest difficulties of the British naval designer for the last 70 years. When the early ironclads were built for the British Navy, it was only an adaptation of the old auxiliary wooden frigate that was designed to work with them, preserving the Trafalgar tradition of carrying a battleship's guns to the limit of her ability. It was difficult to get the speed required by the scouting ships out of a frigate hull with the primitive engines of the 'sixties. Therefore, the need of a smaller ship, armed sufficiently for her purpose only, with comparatively high speed, was soon recognized but it was not until the later 'seventies that it was possible to provide one.

They were really brought into being by the national fear of Russian raids on British commerce, the first true scout cruisers being the *Iris* and *Mercury* of 1877. They were admittedly an experiment, but a very daring one, for mild steel was first used in their hulls and their design was a technical triumph for the date. They had a displacement of 3730 tons; a speed of 18 knots with twin screws and curious tandem engines; and an armament of ten 64-pound muzzle-loaders. Their obvious disadvantages were that their coal supply was only sufficient for a few hours' steaming at full power, and that they relied entirely on their subdivision for protection. They were the first two scout cruisers and well deserve their place in naval history.

ARMSTRONG PROTECTED CRUISERS.

At the time their faults were recognized more widely than their virtues, and after them came a series of overgunned torpedo cruisers and cruisers, generally failing through an attempt to combine many duties, and the essential sea-keeping ability of a British cruiser, on a very small displacement. The Armstrong yard was getting results with the famous protected cruisers which were being built for foreign powers, but these ships, successful as they were, did not possess the qualities which the British Navy demanded. Although they were wonderful ships they were not as faultless as painted at the time. They did, however, lead to a number of small British ships in the 'eighties and 'nineties which were designed very largely for scouting duty with the battle fleets. The "M" class, of 1888, had a displacement of 2800 tons, a speed of 19 knots and an armament of six 6-inch guns. They were regarded as being too large and in the following year the "B" class, 1830 tons, 19 knots and six 4.7-inch guns, were brought out. At the same time, the early "P" class, 2575 tons, mounting eight 4.7-inch guns, gave the desired seaworthiness but their speed of 16½ knots was not sufficient. In the later "P" class the tonnage was cut down to 2135 tons and the armament to eight

4-inch guns, but the speed was increased to 20 knots, which was very much more useful although all these ships had the disadvantage of shortness which made them lose speed in a seaway and rendered them useless as scouts, for in bad weather the battleships which they were supposed to be screening could walk past them.

Then came the numerous cruisers built under the Naval Defense Act, which were the best all-round cruisers of their day—if any cruiser which is designed to undertake many duties can be really satisfactory. They had a margin of 2½ to 3 knots over the contemporary battleships, which was not really sufficient for scouting work, but their powerful batteries of 6-inch and 4.7-inch guns were very useful and they led to the *Dido* and allied classes of about 5600 tons, again with rather disappointing speed, although in the *Vindictive* branch of the family an attempt was made to combine scouting with ramming duties.

GERMAN POLICY.

For the greater part of this time the German Navy was pursuing a steady policy of building two cruisers a year designed both for squadron work and for cruising on the distant stations. There are both advantages and disadvantages in this policy of regular programs; the shipbuilding industry has the assurance of regular work but there is a tendency to get into a rut in the main principles of design while minor points are constantly being tinkered with to an extent which destroys homogeneity.

On the balance, however, the advantages of the German policy appear to outweigh the disadvantages and at the outbreak of war their cruiser fleet was a very formidable one and proved its worth in several actions in the North Sea, although most of the older ships were undergunned.

THE "NOVIK."

In the meantime, the German shipbuilders had designed a ship for the Russian Navy which quite upset all preconceived ideas of a scouting cruiser. She was the famous *Novik*, built in 1900 and really an enlarged destroyer with a displacement of 3000 tons, a trial speed of 26 knots and a battery of six 4.7-inch guns. Handled by one of the smartest officers in the Russian Navy, she proved herself extraordinarily useful as a scout to the Port Arthur fleet during the Russo-Japanese War, but her great fault was small bunker capacity and eventually she was driven ashore with swept bunkers in attempting to escape after the Battle of Round Island. Nevertheless, her qualities made all the other navies of the world think deeply and caused the British Navy to embody certain features of her design into a number of scout cruisers which also satisfied the Navy's demand for cruiser qualities as far as possible.

The faults of the *Novik* were obvious and the Director of Naval Construction was not running similar risks. So the *Gem* class, although having the same displacement of 3000 tons, aimed at a speed of 22½ knots only but stowed 500 tons of coal, mounted twelve 4-inch guns and had very reasonable protection, while the class introduced the turbine engine to the cruiser type in H.M.S. *Amethyst*.

At the same time the Admiralty decided to let the designers of the crack shipbuilding firms put forward their own ideas in the "Scout" class, of which there were two each in the *Attentive, Forward, Pathfinder* and *Sentinel* types, each taking full advantage of the ingenuity of the private designers. Any faults that they possessed, principally in the matter of poor armament and coal supply, were in the specification supplied by the Admiralty, but

they were really remarkable little vessels with a displacement of about 2850 tons, a speed of 25 knots and an armament of ten 12-pound guns which were afterwards changed for 4-inch.

THE "BOADICEA" TYPE.

The fault of these ships, again, was principally in their fuel capacity and in 1907 the *Boadicea* type started a new era with a displacement of 3300 tons, an armament of ten 4-inch and a speed of 25 knots, with excellent coal and oil bunkers. These ships were small for knockabout North Sea work but they proved useful leading flotillas for the Grand Fleet and they rapidly developed in design, various duties being piled onto the original fleet work idea, until they had become what Mr. Winston Churchill aptly described as "destroyers of destroyers." That was a very useful role, but it did not provide a scouting line for the fleet.

When war broke out, in fact, the cruiser screen of the Grand Fleet left a good deal to be desired in the matter of completeness and was composed very largely of the Town class of general-utility cruisers which started under the 1908 estimates with a displacement of 4800 tons, a speed of 25 knots, and an armament of two 6-inch and ten 4-inch guns, and finished under the 1911 estimates with a displacement of 5440 tons, a speed of 25½ knots and a battery of nine 6-inch guns.

As the war progressed, this cruiser screen was improved, although at the Battle of Jutland it was none too strong for maintaining contact with the enemy, and the reliance on the Harwich Force of "C" class cruisers as a reserve proved very difficult to carry into effect in an emergency.

These ships of the "C" class, and later of the "D" class, which was really the steady development of the same idea, were originally conceived for scouting and fleet duties but any number of other jobs were found for them. They began under the 1913 estimates with a displacement of 3750 tons, a speed of 28½ knots and an armament of two 6-inch, eight 4-inch guns and four torpedo tubes, and they finished under the 1918 emergency war program with a displacement of 4850 tons, a speed of 29 knots, and an armament of six 6-inch and three 4-inch anti-aircraft guns backed by twelve torpedo tubes. Unfortunately for the fleet at the present time the older ships of these types are now worn out while the newer ones are mostly employed on distant stations in default of more suitable vessels.

This leaves the Home Fleet deplorably short of its screen of scouting cruisers, only one squadron of four *Leanders* in peace time and very few reserves of the old "C" class to draw upon in an emergency. This means that the fleet will have to rely very largely on destroyers for scouting, and although the British destroyers are among the finest sea boats of their type in the world, they are only destroyers and can be worn out. Therefore the necessity of considering the construction of scout cruisers, leading to the design of the *Arethusa* type, is obvious.

WHAT OF THE FUTURE?

The question is whether, in the circumstances which are likely to rule in the next naval war, the British Admiralty is wise to attempt to evolve a scouting cruiser, capable of doing a cruiser's ordinary duties when necessary, or whether it would not be better to rely for fleet scouting work on the super-destroyers which have been built for the French and Italian Navies. These have generally been called "flotilla leaders," although they are not intended to lead flotillas, but as neither France nor Italy signed the London Treaty they are permitted to give them any name that they think suitable.

The Italians frankly call their ships "scouts," and this would appear to be a large part of their purpose in wartime. The latest Italian ships of this type have a light displacement of 1628 tons, a nominal speed of 38 knots with anything up to 44 knots on trial, and an armament of six 4.7-inch guns and six torpedo tubes, while the latest Frenchmen have a light displacement of 2569 tons, a nominal speed of 37 knots and an armament of five 5.5-inch guns and nine torpedo tubes. The French and Italians are at liberty to call these ships whatever they please, but while the Treaty of London operates the British must call them cruisers and must deduct their tonnage from the quota allowed by international agreement.

The problem of adequate scouting facilities will certainly have to be considered in the next British programs, for we have not yet reached a stage of development where there is safety either in flying boats, seaplanes, or the recently invented American ray for the detection of enemy forces. The scouting line must not only make contact with the enemy but must hold it and for this purpose nothing but a surface ship will suffice. It would appear that the French and Italian super-destroyers are too fragile, fully justifying the British *Arethusa* type. But the design for such a ship must expect criticism and with changed ideas of cruiser construction it is difficult to refute this criticism completely without actual experience.—"Shipbuilding and Shipping Record," 15 August, 1935.

CAPITAL SHIPS OF THE FUTURE.

That the construction of capital ships will begin in this country, the United States, and Japan immediately after the lapse of the Washington Treaty on December 31st, 1936, appears to be a foregone conclusion. Even if those three Powers wished to prolong the battleship "holiday" proclaimed in 1922, they would find it impossible, for other nations are already building vessels of this type, including units larger and more formidable than the strongest now possessed by either of the three navies mentioned. Mr. Swanson, Secretary of the U. S. Navy, announced last month that the Estimates for his Department next year would probably include an appropriation for one battleship. Here, at home, it has recently been stated, apparently with authority, that the Admiralty proposes to build five battleships in the period 1937-39, inclusive, to replace the five *Queen Elizabeths*, all of which will be over the age limit by the end of next year. Japanese plans have yet to be published, but it is a safe prediction that capital ships will be laid down at the earliest possible moment. Probably, therefore, the naval constructors in all three countries are preparing tentative designs for the new mastodons. It is unlikely that their final dimensions and armament will be determined until the next Naval Conference has met, for in British circles the hope is still cherished that a reduction in the existing standard of 35,000 tons may be effected. American naval opinion, it is true, remains hostile to interference with this maximum, but it does not follow that the last word has been said. A compromise somewhere between the "Washington" standard of 35,000 tons and the British Admiralty's suggested figure of 25,000 tons may yet be reached. Save for a minority of super-ship enthusiasts, most of whom live across the Atlantic, naval students are agreed that a 35,000-ton capital ship is needlessly large for the functions she has to perform.

A survey of the capital ships now on the stocks or projected reveals the diversity of the tactical and strategical ideas which inspired their design, and not less those political motives which, for the moment, are almost paramount in the realm of warship construction. The first ship of capital rank to be

started after the war was the U. S. *Colorado,* laid down in 1919, with a standard tonnage of 32,500 tons and a main armament of eight 16-inch guns. In the following year her sister ship, *West Virginia,* was begun. These vessels of the *Maryland* class, the nameship of which originated in 1917, were avowedly designed to counter the Japanese *Nagato* and *Mutsu,* laid down in 1917-18, of 32,720 tons and eight 16-inch guns. Then came the Washington Conference, at which a decision was reached to hold up all capital ship construction for ten years. An exception was made in favor of the British Empire, which was authorized to construct two new capital ships, not exceeding 35,000 tons, as a counterweight to the post-Jutland units already built or laid down by America and Japan. In this way the *Nelson* and *Rodney* came into being. At the London Naval Conference, held in 1930, the battleship "holiday" was extended by six years. At that date, it is important to remember, there was no indication of the German naval revival, which is now playing havoc with all previous estimates of relative strength at sea. Had that development been foreseen the London Naval Treaty would certainly not have been drafted in its existing form. In the meantime, Germany, bound by and still loyally observing the provisions of the Versailles Treaty, put on the blocks in 1929 the first of her famous "pocket battleships," the *Deutschland.* This is a vessel of only 10,000 tons, but she mounts the relatively prodigious armament of six 11-inch guns, and her high-speed oil engines not only give her a contract speed of 26 knots, but endow her with an almost fabulous radius of action. While fully recognizing the technical achievement represented by this German type, we have never shared what we believe to be the exaggerated opinion of its fighting value current in other quarters. In spite of her impressive armament, the *Deutschland* is essentially a cruiser with a speed inadequate for cruiser duties. Except, perhaps, in a sea like a millpond, she would stand little chance in action with a capital ship, while cruisers of her own tonnage could easily avoid her by their superior speed. It is as a potential raider of commerce, rather than as an all-round fighting ship, that the *Deutschland* impresses the imagination. She and her sister ships were built, we believe, less with a view to fulfilling some definite function in the scheme of naval strategy than with the idea of showing the world that German technical skill was able to overcome the handicap imposed on German naval development by the Versailles "dictate." In other words, the design was mainly a sop to national pride, and sentiment so far overrode practical considerations that the colossal bill for the *Deutschland,* amounting to nearly £4,000,000, or £400 a ton, was paid without a murmur. Conclusive proof that the "pocket battleship" type is not considered to be really valuable is supplied by the fact that when the German Government decided to ignore the naval restrictions of the Versailles Treaty it promptly scrapped the *Deutschland* design and laid down ships of 26,000 tons. The country most impressed by the "pocket battleship" was France. The effect of its appearance was dramatic enough. Almost overnight the French naval program, till then limited to submarines, cruisers, and light surface craft of unusual speed, was recast. The capital ship, previously derided as a useless relic of the past, was reinstated as the cardinal factor in sea warfare. Numerous designs for great ships were prepared, and three years were spent in considering their respective merits. Finally, in 1932, there was laid the keel of the *Dunkerque,* a battle cruiser of 26,500 tons, a speed of 29 to 30 knots, and a main battery of eight 13-inch guns. Two years later a sister ship, the *Strasbourg,* was begun.

Primarily, as we have observed, the *Dunkerque* class was built as a reply to the much smaller and weaker German units, but the action of France has had unexpected results which bring out very clearly the interdependence

of national naval policies in the present era. Italy, to preserve the balance of power which she believed to be threatened by the new French battle cruisers, has gone one better by laying down two vessels of 35,000 tons each. As the horsepower of this class is officially returned as 125,000, they are obviously battle cruisers, their armament being reported as nine 15-inch guns. In fighting power, therefore, their margin of superiority over the *Dunkerque* will be almost as great as that of the French ship over the *Deutschland*. France has accepted the challenge by authorizing the construction this year of a 35,000-ton ship and of a second in 1937. Eventually, therefore, she will have four new capital ships as against Italy's two, and so we arrive at the inescapable conclusion that Germany, in building the 10,000-ton *Deutschland*, has directly promoted the construction of nearly 200,000 tons of French and Italian battleships. Apart from the *Dunkerque*, there is little reliable information as to the armament of this new fleet of capital ships. The Italian *Vittorio Veneto* and *Littorio* are unofficially reported to have nine 15-inch, while the French 35,000-ton type is credited with twelve 13.4-inch guns in quadruple turrets. From Washington comes a forecast of ten 16-inch as the armament of the projected American battleship. The British Admiralty keeps its own council, but it is fairly evident that our next heavy ships will not follow too closely the design of the *Nelson*. In this year's prize essay of the Royal United Service Institution, the author, Lieut. Bennett, R.N., urges the claims of a ship of 27,000 tons, with a speed of 25 knots, a main armament of nine 13.5-inch, and a secondary battery of sixteen 4.7-inch, equally available against either surface or air targets. Much as we dislike exaggerated dimensions, we should not feel quite comfortable were the future British Battle Fleet to be composed of ships of this type while other fleets included a majority of 35,000-ton vessels, mounting 15-inch or 16-inch guns. Nor do we believe the Admiralty would be content with such a marked disparity.

Until the unfortunate London Treaty forced our hands in respect of cruisers, it was never our policy to build warships palpably inferior to those of other navies, and we find it hard to believe that such a policy will be adopted when the time comes to restore our dilapidated Battle Fleet. Most probably, therefore, no final decision as to the size and gun-power of future British capital ships will be taken until the authorities have information about the building proposals of foreign Governments. What we already know is that the smallest capital units now building abroad are of 26,000 tons and the largest of 35,000 tons. Whether we shall build to the maximum or content ourselves with a displacement figure somewhere between the two remains to be seen. However much we may regret the American passion for mammoth ships, it may be accepted as certain that no suggestion of a building race with the United States will be tolerated by any party in the State. Hence the dimensions and armament of our new capital ships will be determined by the general trend of foreign construction. On this point it is enough to say that neither in European nor Asiatic waters can we be satisfied with ships that are in any respect inferior to the foreign men-of-war normally to be encountered there.—"The Engineer," 16 August, 1935.

INCREASING ANTI-AIRCRAFT BATTERIES.

One of the most awkward of the minor operations to carry out really satisfactorily on a man-of-war which is already completed is the installation, or increase, of efficient anti-aircraft batteries. The very complete modernization which has been carried out in American and Japanese ships has permitted

this work to be done fairly satisfactorily, but in British capital ships the modernization process has generally been much more moderate and comparatively little improvement has been effected. The result has been that, generally speaking, the high-angle batteries of British ships have been inferior to those of their foreign rivals. In the *Royal Sovereign* class, for instance, the main anti-aircraft battery is four 4-inch, while the Japanese *Fusho* mounts eight 5-inch, as does also the American *Pennsylvania*. The British *Washington* cruisers mount four 4-inch but the French *Algerie* mounts 12 and the Italian 10,000-tonners no less than 16 3.9-inch pieces. This, of course, is in addition to pom-poms and machine guns in which it is believed that the British service has a comfortable superiority over its rivals. The *Warspite* and *Malaya*, which are now being refitted, will according to rumor, emerge with their anti-aircraft guns doubled in number and very considerably improved in quality, while it is understood that in the designs of the new ship which will be laid down from 1937 onwards, very particular attention is being paid to the anti-aircraft batteries which will be far more powerful than anything that has hitherto been considered in the Royal Navy.—"Shipbuilding and Shipping Record," 29 August, 1935.

LAUNCH OF H.M. SUBMARINE *NARWHAL*.

On Thursday, August 29, 1935, the launch of his Majesty's submarine *Narwhal* took place at the Naval Construction Works of Vickers-Armstrongs, Ltd., Barrow-in-Furness. The ceremony was performed by Mrs. Henderson, the wife of Vice-Admiral R. G. H. Henderson, Third Sea Lord, and Controller of the Navy. At the luncheon which followed the ceremony, Colonel J. B. Neilson, the deputy chairman of Vickers, Ltd., and of Vickers-Armstrongs, Ltd., who presided in the unavoidable absence of the chairman, pointed out that as far back as 1900 an arrangement had been made to allow the Holland Patents to be used at Barrow. These patents were in the hands of the Electric Boat Company of America, and covered forms of submarine construction. H.M.S. *Narwhal* is the 167th submarine to be launched from the Barrow shipyard. The *Narwhal* is a submarine of the *Grampus* class, which includes two sister ships, the *Grampus* and the *Porpoise*, the former having been built at Chatham and the latter by Vickers-Armstrongs. Reports of their performances mention a surface speed of about 15 knots, and a submerged speed of about 8¾ knots. The displacement figures are given as about 1520 tons on the surface, and about 2140 tons submerged. Their engine horsepower is stated to be 3300 and the electric drive horsepower, 1630. The class is reported to be adapted for minelaying, while their armament is given as one 4.7-inch gun, two smaller guns, and six torpedo tubes.—"The Engineer," 6 Sept., 1935.

X-RAY AND WELDING
THE FOUNDRYMAN'S AID TO QUALITY STEEL CASTINGS.

By C. M. Underwood* and E. J. Ash,* Washington, D. C.

ABSTRACT.

This paper reviews the assistance that X-ray studies and welding of steel castings has rendered the Naval Gun Factory. The paper discusses the routine inspection of production castings, the examination of pilot castings and the

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cooperative procedure followed in salvaging castings by removing the defects and welding, together with some of the problems involved. The changing of patterns to avoid tears and shrinkage areas is also discussed and illustrations are shown. Some other problems reviewed are: Welding low alloy castings susceptible to air hardening, possibilities of removing hardness by proper bead sequence, and removal of stresses produced by weld heating and contraction. A number of illustrations of methods of preparing welds for gun carriage castings are shown.

1. Radiographic examination of steel castings is a relatively new method for studying the fitness and quality of castings for service. This type of examination is unique in the sense that the quality of a casting is not only based upon the chemical and physical properties of the metal from which the casting is made and the surface appearance of the casting, but upon the soundness or continuity of the internal metal. In the final analysis, the latter factor should be the criterion for determining the fitness of castings to withstand shock and repeated stress.

2. This paper will review the assistance that X-ray and welding studies of steel castings has rendered the Naval Gun Factory in three phases of its work. These phases comprise the routine inspection of production castings, the examination of pilot castings, and the cooperative procedure followed in salvaging castings by removing the defects and welding; together with some of the welding problems involved.

X-RAY EQUIPMENT.

3. In June, 1934, the Naval Gun Factory purchased a portable X-ray machine, specially designed and built for ordnance requirements. The two salient features of this machine are its portability and flexibility. The machine is a self-contained unit, mounted on a truck (see Figures 1, 2 and 3) and can be moved from shop to shop or wherever its use is required. The only service necessary is a 220 volt, single phase power source. The machine has a variable voltage up to 220,000 on the secondary or tube circuit and is satisfactory for radiographing castings and welded plates up to 3½ inches in thickness.

4. The protective head, enclosing the shockproof X-ray tube, is mounted on a stand capable of 280 degrees horizontal rotation and with the additional vertical and traversing adjustments will cover any point of an imaginary figure 8 feet cube. It is thus possible to examine a comparatively large casting by moving only the adjustable head rather than the material or the machine.

Shielding Operator.

5. One of the difficulties normally encountered with X-ray operation is in shielding the operators or surrounding personnel against harmful rays. The conventional arrangement is to have a lead lined room in which the X-ray tube is located. Work must be placed on a truck or in some similar way transported into this room. In order to turn the work it must be removed from the room for accessibility to crane service. An alternative, is to have a removable roof over the lead-lined chamber but this method is often equally cumbersome.

6. The expense of building a lead-lined room of sufficient size to handle large castings may be excessive. This difficulty has been effectively overcome in the Naval Gun Factory machine by enclosing the X-ray tube itself in a lead-lined casing. An aperture is provided in the casing that will permit emission of the X-rays only in a controlled direction or toward the section under examination.

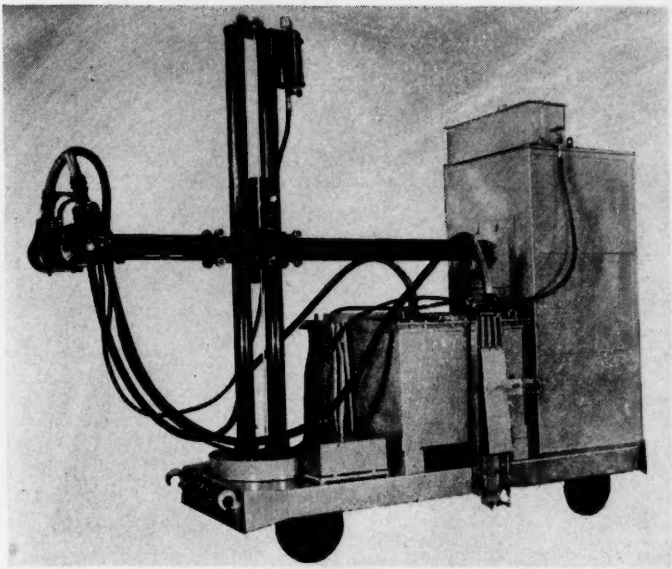

FIGURE 1.—PORTABLE X-RAY MACHINE WITH SHIELDED, SHOCKPROOF, ADJUSTABLE HEAD; OIL IMMERSED TRANSFORMER AND RECTIFYING UNIT, AND CONTROL CABINET.

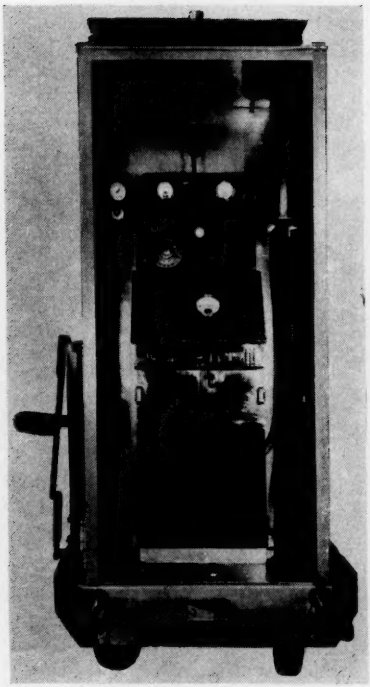

FIGURE 2.—CONTROL BOOTH OF PORTABLE X-RAY MACHINE. INSTRUMENT PANEL AND REGULATING SWITCHES ARE SHOWN.

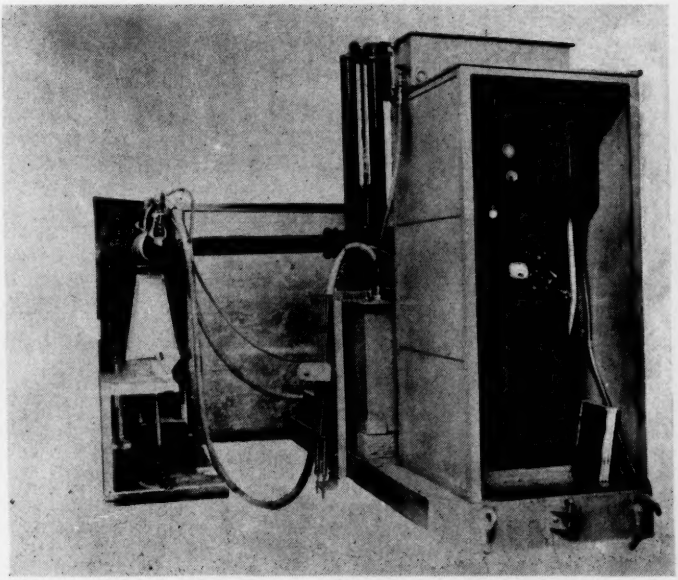

FIGURE 3.—RADIOGRAPHING STEEL CASTING. X-RAY HEAD IS IN POSITION OVER AREA BEING EXAMINED. SMALL LOCAL LEAD SHIELD IS PLACED BETWEEN HEAD AND CASTING. LEAD-LINED SCREENS ARE SHOWN BEHIND THE MACHINE.

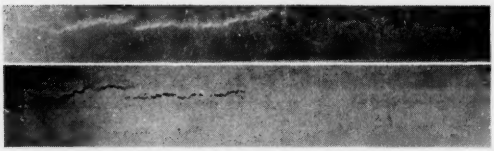

FIGURE 5.—UPPER SECTION RADIOGRAPH OF STEEL CASTING WHICH APPEARED PERFECT BUT CONTAINED INTERNAL TEARS AND SHRINKAGE. LOWER SECTION PHOTOGRAPH OF THE SAME AREA AFTER SUFFICIENT METAL WAS REMOVED TO DISCLOSE SOME OF THE DEFECTS.

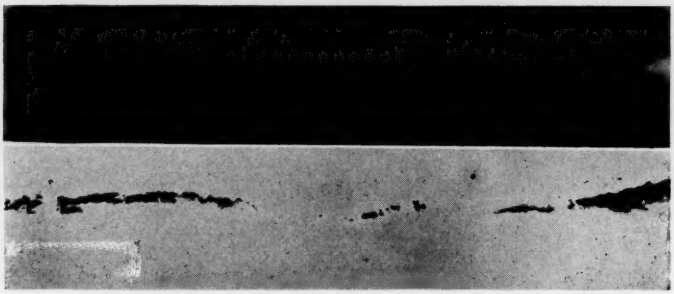

FIGURE 6.—UPPER SECTION RADIOGRAPH OF STEEL CASTING WHICH APPEARED PERFECT BUT CONTAINED INTERNAL TEARS AND SHRINKAGE. LOWER SECTION PHOTOGRAPH OF THE SAME AREA AFTER SUFFICIENT METAL WAS REMOVED TO DISCLOSE SOME OF THE DEFECTS.

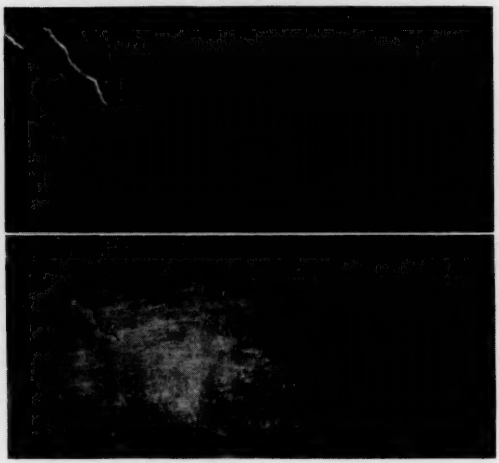

FIGURE 7.—UPPER SECTION RADIOGRAPH OF STEEL CASTING WHICH APPEARED PERFECT BUT CONTAINED INTERNAL TEARS AND SHRINKAGE. LOWER SECTION PHOTOGRAPH OF THE SAME AREA AFTER SUFFICIENT METAL WAS REMOVED TO DISCLOSE SOME OF THE DEFECTS.

7. Movable lead-lined screens are also provided about the work and small lead plates may be used as an additional protection to stop scattered or secondary radiation. This shielding arrangement has proven adequate as periodical medical examination of personnel working with the equipment has disclosed no harmful results. The small amount of lead shielding required is sufficiently flexible to permit ready handling of material with cranes about the machine.

8. As a further precaution the machine controls are located in a lead-lined cabinet at the rear of the machine. The X-ray tube is immersed in an oil of exceptionally high dielectric strength as are the rectifying or kenetron tubes. The machine is equipped with a pump which circulates oil through the target of the X-ray tube during operation so excessive temperatures will not result from sustained operation.

ROUTINE INSPECTION OF CASTINGS.

9. The Naval Gun Factory machine has been in daily use since its installation and for several months was operated 16 hours per day. As a result of the ability of this machine to detect internal defects and probable sources of weakness, X-ray examination of important ordnance castings is required as a routine step in production. An essential feature of this type of testing is the speed with which final results are obtained. The average procedure is to expose the film from 1 to 5 minutes and develop it in the same manner as other photographic films. The entire processes can normally be performed within 20 minutes.

EXAMINATION OF PILOT CASTINGS.

10. Another practical application of the X-ray type of examination is the study of newly designed castings. The examination of pilot castings reveals any defective areas that occur and are likely to repeat in production of subsequent work. Corrective action may then be taken.

11. By varying the casting design and foundry practice to produce a sound casting, the costs of subsequent repair or total rejection, either during the machining operations or later in service, may be avoided.

12. Such analyses of pilot castings form a potent tool in the making of quality products. It is obvious that X-ray is one of the most searching non-destructive means of examination available.

Examples of Pilot Castings.

13. The following examples will serve to illustrate the part that may be played by X-ray in the production of sound steel castings. Figure 4 is a partial sketch of a 5-inch slide casting weighing about 4000 pounds. Although the outer appearance of the casting was satisfactory, radiographic examination disclosed numerous hot tears near the trunnions or cylindrical side projections.

14. The upper sections of Figures 5, 6 and 7 are radiographs of typical defective areas that appeared sound upon the surface. The lower section of each of these figures is a photograph of the area after sufficient material had been removed to disclose the defects.

15. In service, the trunnion sections of the pictured slides are highly stressed areas and subject to repeated load. Some of the defects observed were of a nature subject to propagation and were therefore undesirable. A cross-section of the original design is shown in the upper part of Figure 4. It will be observed that the vertical walls are of equal section.

16. The hot tears and shrinkage defects occurring in the original design were eliminated by tapering the sidewalls as indicated in the lower sketch of Figure 4. This is a simple illustration of directional solidification.

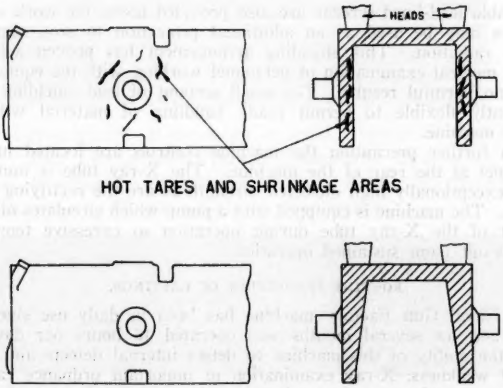

FIGURE 4.—SECTIONAL SKETCH OF 5-INCH 38 CALIBER SLIDE CASTING. ILLUSTRATION SHOWS LOCATION OF INTERNAL DEFECTS LOCATED BY X-RAY AND CORRECTIVE CHANGE EMPLOYED.

17. A similar case is a gun director stand casting weighing approximately 1200 pounds, sketched in Figure 8. Radiographic examination showed shrinkage defects in the region indicated. In addition to the tapered section as pointed out above, it was further necessary to place blind risers as illustrated. This practice eliminated the defects from the areas in question. Thus by radiographic examination it is possible to produce castings of known soundness, minimizing the chance of having internal defects subsequently appear.

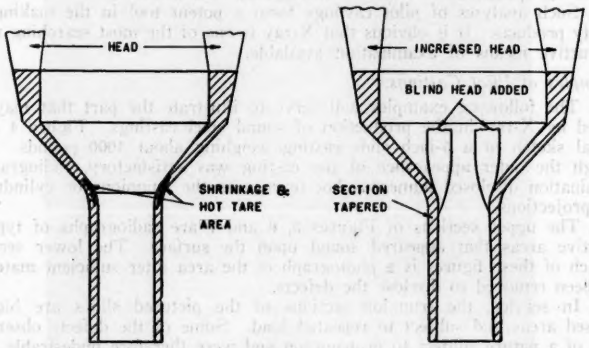

FIGURE 8.—SECTIONAL SKETCHES OF GUN DIRECTOR STAND. ILLUSTRATION LOCATES X-RAY DETECTED DEFECTS AND SHOWS CORRECTIVE MEASURES TAKEN.

PREVIOUS WELDING LIMITATIONS.

18. Welding has formerly been used to a limited extent in repairing quality steel castings. Minor surface repairs have been permitted where stress of low magnitude were involved and a satisfactory finish was essential. Some form of electric arc welding has generally been employed for the most economical results.

19. For a number of years carbon arc welding was used extensively, but deposition by this method is usually lacking in the desirable physical characteristics. Metallic arc welding with bare electrodes has been used more recently. Depositions with this material produce physical properties ranging from 55,000 to 60,000 pounds per square inch tensile strength, but having only 2 to 8 per cent elongation, with fatigue and impact properties proportionately poor.

20. Until such time as better welding materials became generally available, the application of casting repair by welding was obviously limited. During the past several years, however, a very satisfactory type of mild steel, covered welding electrode has been developed.

PROPERTIES OF DEPOSITED MATERIAL.

21. Covered electrodes are now used extensively for numerous forms of fabrication. The properties of the deposited material acceptable for naval use range from 60,000 to 70,000 pounds per square inch tensile strength, 45,000 to 55,000 pounds per square inch yield point, 20 to 30 per cent elongation in 2 inches, 60 to 75 foot pounds Izod impact values, 26,000 to 30,000 pounds per square inch endurance limit and other physical properties proportionately satisfactory.

22. To keep pace with the rapid advancement and more general use of alloy steels, numerous types of covered, alloyed rods have also been developed. More outstanding among these are the ferrous alloys of manganese, nickel, molybdenum, nickel-copper and manganese-vanadium.

23. The alloying elements in weld deposits are obtained by using an alloy steel core, by pick-up through chemical reaction with the covering or by a combination of the two methods. Tensile strengths ranging from 80,000 to 110,000 pounds per square inch, with elongations varying from 25 to 15 per cent are obtainable.

24. The alloy rods as yet have not had the extensive application of mild steel electrodes, but some of them appear particularly promising and may prove entirely satisfactory for application where higher physical properties or homogeneity of repaired section are essential.

WELDING PROCEDURE APPLIED TO CASTING REPAIR.

25. Mild steel in its various rolled forms is now extensively fabricated by the use of arc welding. When similar welding procedures are applied to steel casting repair, however, unsatisfactory results are often obtained. Casting repair involves a number of peculiarities which must be taken into consideration.

26. Many steel castings are of a chemical composition not ordinarily suited for welding. Alloying elements, such as carbon, chromium, nickel, manganese and silicon are common hardening elements which are affected by welding temperatures. Carbon being the most potent alloying element, should be kept within satisfactorily low limits; preferably not exceeding .18 to .25 per cent.

27. The greater the amount of metallic alloying elements the more the necessity for lower carbon content. It has been the contention of numerous

foundrymen that carbon contents of .15 to .20 per cent do not pour satisfactorily for complex designs. It is the opinion of the Naval Gun Factory, that even though the low carbon content may be conducive to some defects, it is better to have castings that can all be readily repaired by welding; than to have castings with fewer defects, but which cannot be satisfactorily repaired by welding.

28. The amount of manganese, nickel, or chromium employed as alloying elements is usually determined by the physical requirements to be met. Molybdenum and vanadium, in quantities commonly used, can fortunately be made to improve physical properties and at the same time produce a material that is weldable.

Low Alloy Castings Susceptible to Air Hardening.

29. When it is necessary to weld low alloy castings which are susceptible to air hardening, several procedures may be followed. The castings may be preheated in order to retard the quenching effect of the casting mass surrounding the heated area adjacent to the weld deposit, thus preventing undue hardness.

30. Preheating is usually accomplished by means of oil or gas burners placed at numerous locations about the casting to be welded. Where facilities are available, furnace heating of the casting is preferable, as more uniform temperatures are possible. The casting can be removed from the furnace for welding and replaced in the furnace at intervals in order to maintain the temperature within satisfactory limits.

31. For larger castings where furnace facilities are not available, charcoal fires may prove satisfactory. Preheats of 200 to 400 degrees F. are usually sufficient for low alloy content castings. Materials readily air hardenable may require much higher temperatures, however.

32. Repairs are often necessary in difficult places, such as in internal parts of castings where it is impossible for operators to work on preheated material, so resort must be made to other methods. The use of higher currents, in applying the weld, although adverse to conventional practice, is effective. This practice makes a larger heat affected zone, but a more gradual hardness gradient from the inner hard area to the outer less hardened or unaffected area. The quenching effect will not be so rapid and stress concentrations will not be as severe.

Multiple Layer Effect.

33. By spreading out the heat affected zone resulting from the first layer of weld metal applied, subsequent layers of weld metal can be added over the first while the welded area is still warm. The heat of the second or subsequent layers will penetrate through the first layer and into the heat affected zone sufficiently to draw the major portion of the hardness. By properly timing this multiple layer sequence, it is possible to produce a weld without detrimental effect in a casting that is normally air hardening. Where large areas are to be welded the cast steel surface can be covered by such a multiple layer method. After having once covered the area in this manner, it is possible to continue welding with no further precautions than are necessary on a similar mild steel material. The additional deposits will, of course, be placed entirely on the weld metal which does not have air hardening properties.

Materials Subject to Air Hardening.

34. The sections shown in Figure 9 demonstrate the possibilities of removing hardness by proper bead sequence. A single layer weld on a steel very susceptible to air hardening (carbon 0.39 per cent, manganese 0.63 per cent,

silicon 0.22 per cent, nickel 2.99 per cent, sulphur 0.038 per cent and phosphorous 0.043 per cent) will give Vickers* hardness readings up to 579. A second bead reduced the hardened zone resulting from the first bead to 318, but created a second heat affected zone with a hardness up to 469. A third overlapping bead drew the maximum temper of the first two beads to 287, but produced a maximum hardness of 384 in its own small heat affected area. A fourth overlapping layer was sufficient to remove the major portion of the remaining hardness, reducing it to 270-280 as compared with 230-260 of the original material.

PREPARING CASTINGS FOR WELDING.

35. In preparing castings for welding, all scale, silicates or other foreign material must be thoroughly removed from the weld area, as these substances will contaminate the weld deposit and cause unsatisfactory physical properties. Where the defects are large they may be removed with gas cutting-torches, lances, or air chisels. An experienced chipper can usually follow such defects as small cracks or hot tears by watching the manner in which the chisel chip splits.

36. When no further defect can be detected, the cavity may be ground and polished for etching. In this manner any small associated defects remaining on the cavity surface are readily detectable. At the same time the groove can be satisfactorily shaped for welding; that is, the walls must not be too vertical, the bottom of the cavity should be properly rounded and surfaces to be welded made reasonably smooth.

37. It is preferable to weld castings in the downhand or flat position. Electrode sizes of 3/16 inch and 1/4 inch are normally used with fairly high currents. This practice does not lend itself to vertical or overhead welding. Where necessary, vertical and overhead welding may be accomplished with smaller rods and lower currents.

APPLICATION IN THIN LAYERS.

38. Weld metal should be applied in thin layers rather than in cylindrical beads wherever practicable. By using the layer method, each deposit may recrystallize the metal previously applied, producing a fine grain structure of superior physical properties.

STRESSES PRODUCED BY HEATING AND CONTRACTION.

39. Stresses produced by weld heating and contraction are the most important factors to bear in mind. Original cracks, hot tears and shrinkage are often due to the designed shape of the casting, or the pouring practice. Frequently these defects occur in or near the junction of light sections to heavy surrounding stiffeners or in lighter sections due to failure of the mold to collapse. The conditions that caused the original defect may also tend to cause the repair weld to crack.

40. The heavy sections rigidly support the defective areas so little contraction can occur while the weld cools. Stresses produced by welding, therefore, must be largely absorbed in the weld metal itself. These stresses increase accumulatively as the welding progresses. Until the time that the weld is completed its cross sectional area is smaller in comparison with the cross

* Vickers hardness readings are used because of the small area required for test. The Vickers numbers listed are Vickers, Pyramidal Diamond, 30 Kg. load, Objective 2/3 in. They correspond closely to Brinell Hardness numbers up to 300 but are increasingly higher than corresponding Brinell readings from there up.

sectional area of the adjacent casting. The incompleted weld deposit, therefore, cannot stand as large a stress as the casting, although the physical properties of the weld deposit itself may be superior.

41. Unless precautions are taken internal cracks may originate in the weld. These cracks sometimes spread as the welding progresses, two or three layers beneath the deposited surface. The cracks may extend 40 to 90 per cent through the weld and still be detectable only by X-ray or similar examination.

DUCTILE MATERIAL MAY CRACK.

42. The improved elastic properties of covered electrode deposits are frequently demonstrated. Yet when the same deposit is made in casting repair, cracks may result with little or no evidence of distortion. This paradox is caused by the complicated stresses that may be set up in welding rigidly supported areas. For example, consider a volume of material acted upon in all directions by forces that are equal and opposite. Although the magnitude of the opposing forces may be varied through wide ranges no distortion will occur as long as the forces remain equal and opposite. No evidence of strain will appear until the cohesive strength of the material has been exceeded. Rupture will then result. Also, with casting repair, contraction may induce heavy stresses that are nearly equal and opposite. The result may be cracks occurring in a ductile deposit with little forewarning evidence of stress. Such cracks are frequently internal.

REDUCING WELD STRESS CONCENTRATION.

43. There are several ways of reducing weld stress concentrations. Preheating causes the weld to cool more slowly so that less stress is set up by the welding operation. Maintenance of the casting, at moderately elevated and relatively constant temperatures, is very advantageous. Expansion and contraction are then held within a small range so that the full effect of shrinkage is not exerted. It is necessary in such cases to work continuously on a job once started until it is completed.

44. On complicated jobs it is preferable to place the finished casting immediately in a furnace for stress annealing without permitting the casting to cool. The additional stresses set up while cooling from the preheat to room temperature are thus avoided.

45. Peening is the most potent means of controlling stresses, preventing cracks and avoiding distortion. This operation must be very carefully done if it is to be effective, however, for misuse may be equally harmful. When peening is to be employed, layers of weld metal should be deposited so that their surfaces are as smooth as possible.

46. Irregularities that occur should be removed by chipping or grinding so equal work will result throughout the deposit from application of the peening tool. All slag or foreign material must, of course, be carefully removed. Peening should follow the smoothing and cleaning operation as quickly as practical.

47. The peening operation is preferably accomplished by means of a rounded or blunt nosed tool in an air hammer. Rapid, light blows should be used so that the metal will flow smoothly, as in the heading of a hot rivet, rather than by heavy blows which may tend to tear or rupture the metal. By peening immediately after welding, while the deposit is still hot, less work is required to accomplish a given result and the metal is more ductile so that detrimental effects are less likely to occur. Peening at this time also prevents contractive stresses which would possibly cause cracking or distortion.

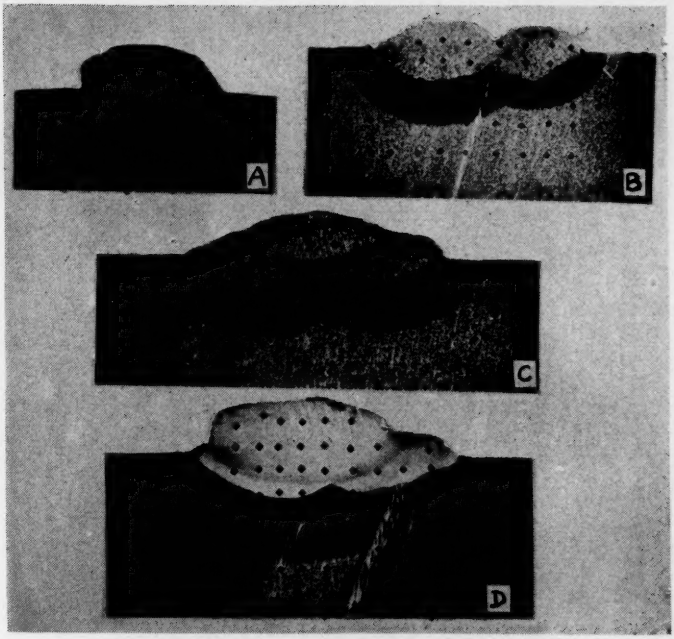

FIGURE 9.—(A) SINGLE BEAD WELD ON AN AIR HARDENING STEEL. AN EXCEEDINGLY HARD ZONE HAS BEEN PRODUCED IN THE BASE METAL ADJACENT TO THE WELD AS EVIDENCED BY THE VICKERS' HARDNESS TABULATIONS.

(B) A SECOND WELD BEAD HAS BEEN LAYED BESIDE THE WELD SHOWN IN *A*. PART OF THE HARDNESS OF THE FIRST PASS HAS BEEN REDUCED, BUT A NEW HARDENED ZONE HAS BEEN CREATED.

(C) A THIRD WELD BEAD HAS BEEN LAYED OVER THE TWO WELD BEADS SHOWN IN *B*. THE HARDENING EFFECT OF THE FIRST TWO BEADS HAS BEEN SUFFICIENTLY REDUCED, BUT A SMALL HARDENED AREA BENEATH THE THIRD BEAD HAS BEEN CREATED.

(D) A FOURTH BEAD HAS BEEN APPLIED OVER THE THIRD BEAD OF *C*. BY THE APPLICATION OF A MULTIPLE LAYER SEQUENCE OF WELDING, HARDENED AREAS IN THE PARENT METAL HAVE BEEN REMOVED.

VICKERS HARDNESS VALUES OF WELD SECTIONS

				A—		306	318	306	337	284	275						
						281	269	289	269	303	279	277					
		236	248	517	543	511	401	376	517	550	579	240	238				
		226	238	242	454	499	499	511	481	406	248	238	236				
		230	232	240	252	248	258	242	244	244	244	236	236				
		228	230	238	238	240	242	238	230	238	238	226	234				
		B—				217	207	214	189	199	224	244					
		236	331	459	228	242	234	221	202	200	248	327	281	260			
		236	254	429	469	318	312	429	429	275	318	337	254	258			
		238	228	256	362	419	429	396	279	267	265	250	256	256			
		240	238	236	236	258	258	244	244	242	250	258	254	260			
		234	238	236	234	234	234	265	244	250	254	246	256	263			
C—						192	204	202	194	194	168						
					198	193	200	198	198	196	198	200	215				
236	232	324	254	221	208	204	202	191	199	200	200	217	337	354	254	269	
242	240	258	331	315	240	199	228	376	275	210	217	324	348	318	263	272	
234	242	234	267	301	303	284	269	246	240	292	318	309	281	250	260	265	
240	238	234	238	236	244	240	242	234	238	234	246	246	252	260	258	265	
234	230	232	242	242	238	234	244	242	242	242	246	252	254	250	263	267	
	D—				167	179	178	178	177	179							
					166	165	166	174	173	166	185	200	185				
	232	242	256	256	174	182	172	172	177	187	193	196	189	240	242	254	
	236	236	244	254	254	215	177	179	298	221	232	267	240	269	240	267	
	242	236	240	250	250	252	256	275	252	246	265	242	238	234	267	267	
	234	236	234	240	246	248	254	248	246	236	269	260	269	269	272	272	
	238	236	242	242	236	230	246	228	240	256	260	267	269	275	275	279	

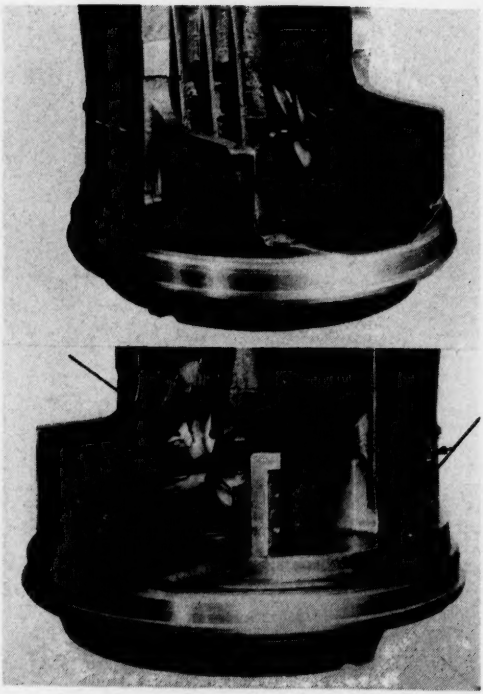

FIGURE 10.—(A) CARRIAGE CASTING FOR 5-INCH 38 CALIBER GUN. DEFECTIVE AREAS HAVE BEEN REMOVED.

(B) FIVE-INCH CARRIAGE CASTING WITH LARGE DEFECTIVE AREAS NEAR BASE.

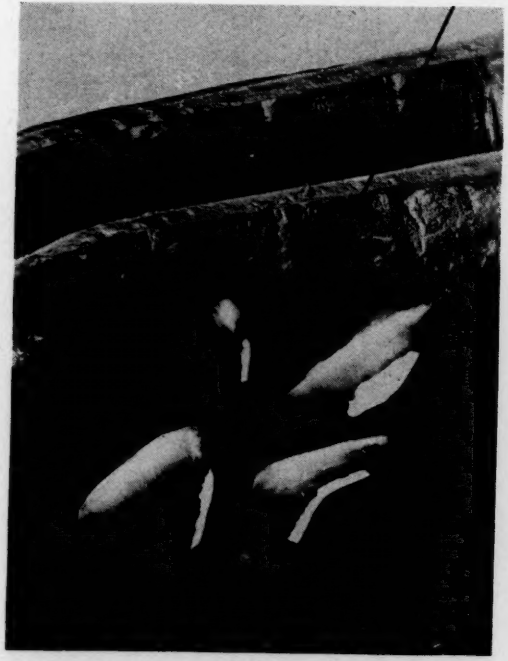

FIGURE 11.—SECTION OF CASTING SHOWING AREAS FROM WHICH DEFECTS HAVE BEEN REMOVED.

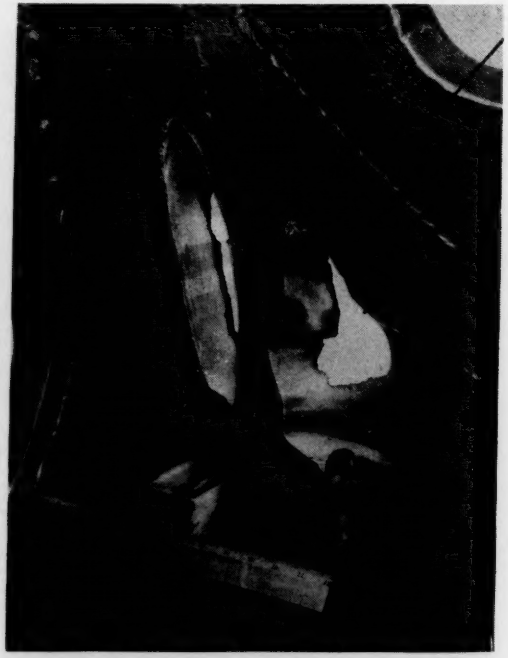

FIGURE 12.—CASTING WITH DEFECTIVE AREA REMOVED. SURFACES HAVE BEEN POLISHED AND ETCHED DURING COURSE OF INSPECTION.

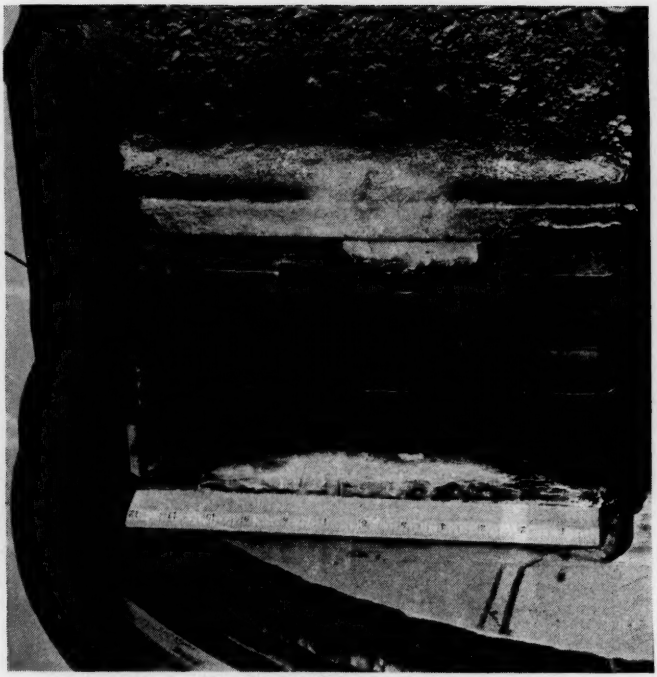

FIGURE 13.—WELDED AREA PARTIALLY COMPLETED. SLAG AND IRREGULARITIES HAVE BEEN REMOVED FROM WELD SURFACE IN PREPARATION FOR PEENING.

Peening Precaution.

48. If the material being welded is subject to air hardening, care must be taken not to peen the first two or three layers, as blows from the peening hammer will be inducive to cracking in the hardened zone beneath the weld deposit. Where the cavity to be repaired extends all the way through the casting the first few layers of weld metal closing the void should not be peened. Sections of this nature may be too thin to withstand the mechanical working and subsequent cracks may possibly develop.

49. Care must be taken that no undue irregularities in the weld surface are peened down, as this will cause folds in the underlying metal which will be covered over and remain as a void in the deposit. Excessive peening must be avoided, as compressive forces can be introduced which are detrimental and in extreme cases may cause warping in the reverse direction to that anticipated. Personnel can be trained so that they can perform peening operations effectively. Little supervision is required once a suitable routine has been established. If peening is properly done it is very helpful in preventing distortion and in the production of satisfactory weld repairing.

Hardened Areas Adjacent to Weld.

50. Castings which have been welded so that hardened areas exist adjacent to the weld should be heat treated in order to relieve this condition. The usual practice of heating slightly above the critical temperature and furnace cooling is a satisfactory method. In some cases it may be practical to weld castings before any heat treatment. Deleterious areas resulting from welding will then be removed during the normal heat treatment cycle subsequently performed on the castings. Such practice must be used with caution, however, as green castings may contain heavy initial stresses, and in their coarse-grained, brittle condition are vulnerable to cracking.

Stress Relieving.

51. Stresses induced by welding may be satisfactorily relieved in most cases at temperatures of 1100 to 1200 degrees F. There is no change in microstructure at these temperatures but the tensile strength of most low alloy steels is reduced to 6000 or 8000 pounds per square inch so that residual stresses in excess of this amount will adjust themselves. Temperatures of this magnitude are usually not sufficient to cause warping of the casting due to its own weight and should not cause heavy scaling.

52. The usual procedure is to heat the casting slowly with the furnace, hold for one hour per inch of thickness of the heaviest section and cool in the furnace. Lower temperatures may be equally effective if employed for sufficiently long periods of time. The required holding periods increase rapidly with lower temperatures so this procedure is usually inadvisable.

AN EXAMPLE OF WELD REPAIR.

53. Naval Gun Factory castings are necessarily of high quality in order to be satisfactory for the exacting requirements of ordnance use. Due to the complicated nature of some parts, however, casting difficulties are sometimes encountered. As a demonstration of the practicability of the foregoing principles an example of weld repair is cited.

54. A number of carriages for a 5-inch 38 caliber gun (main supporting member for the gun and associated mechanism) Figure 10A had been cast, heat treated and finished machined ready for assembly before the X-ray equipment was installed. After X-ray inspection was established it was found that a great many of these carriages had extensive defects in a highly stressed area near the base. Examination of pilot castings and extensive machine

work in the defective area failed to disclose the internal hot tears, although a number of them extended 80 to 90 per cent through the finished cross sectional area.

55. These finished carriages weigh approximately 3000 pounds. In order to reclaim these parts, repair had to be effected without appreciable distortion. After considerable experimenting on sample pieces and pilot models, the repair procedure described below was established.

Removing Defective Areas.

56. Castings were X-rayed in all defective areas and the defects traced on the outside of the casting. Chippers using heavy air operated chisels removed these defective areas. This operation was followed by grinding, buffing and etching in order to further determine that all visible cracks, tears or voids were completely removed, see Figures 10B, 11 and 12. If the defective area did not extend entirely through the casting the remaining cross sectional area was X-rayed in order to detect further tears that might exist beneath the etched surface. This procedure was repeated until all defects were removed. The casting was then ready for welding.

Welding Operation.

57. The carriages were placed in a convenient position for welding and preheated to between 200 and 300 degrees F. A definitely timed welding cycle was started and continued at a rate that would maintain the casting at this temperature until the weld was completed. The welding cycle consisted of applying a layer of weld metal in the defective area, removing the slag from the weld, grinding, or chipping irregularities from the weld surface when necessary and chipping out any defects from the weld deposit, such as gas holes, slag inclusions, etc., Figure 13.

58. Following this preparation, the weld was peened by an especially trained operator who had been taught the correct amount of peening from practicing on pilot samples. A crew of men trained for the welding, chipping and grinding operations performed their successive duties in the required order on several castings. The number of castings worked upon at a time depended upon the size of welds but care was taken so the time interval automatically maintained the desired temperature in each casting. All welds were reinforced or built up approximately ¼ inch thicker than the casting before being permitted to cool.

59. After the welding was completed and the casting had cooled sufficiently, the excessive weld metal was removed, the area polished, ground, etched and examined for surface defects (Figures 14 and 15). All welded areas were then X-rayed. If any further defects in the casting or cracks and tears in the deposited weld metal had developed during the welding operation, the defects were removed and the repair process repeated. In this manner all questionable areas were eliminated.

Stress Relieving Treatment.

60. After completion, the carriages were placed in an especially constructed stress-relieving furnace. This furnace, Figure 16, was designed so that heat would be applied only to the repaired area and no oxidation resulted on the trunnion-bearing supports. The heat gradient was gradual between the heated portion and the external sections so no serious stresses were introduced. The welded area was gradually heated to a temperature of approximately 1100 degrees F. during a period of 8 hours, held at this temperature for 3 hours and permited to cool in the furnace for a period of 12 hours. The carriage was then removed and the light oxide buffed from the finished machined surfaces.

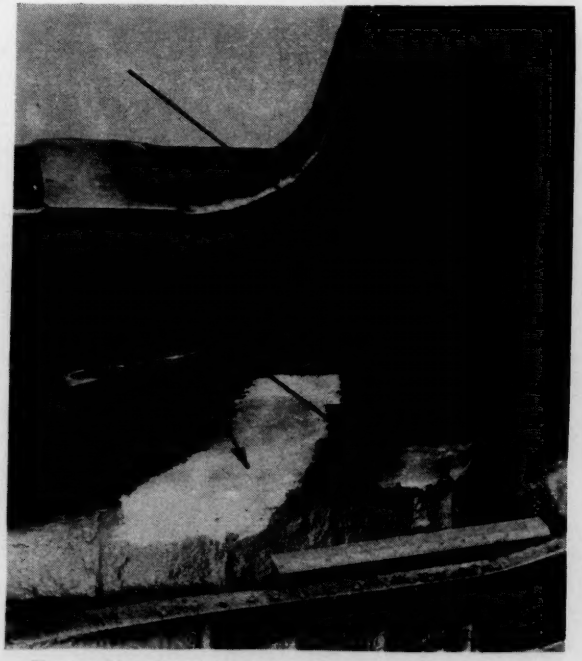

FIGURE 14.—COMPLETED WELD REPAIR. REINFORCEMENT HAS BEEN REMOVED, SURFACES POLISHED AND PARTLY ETCHED.

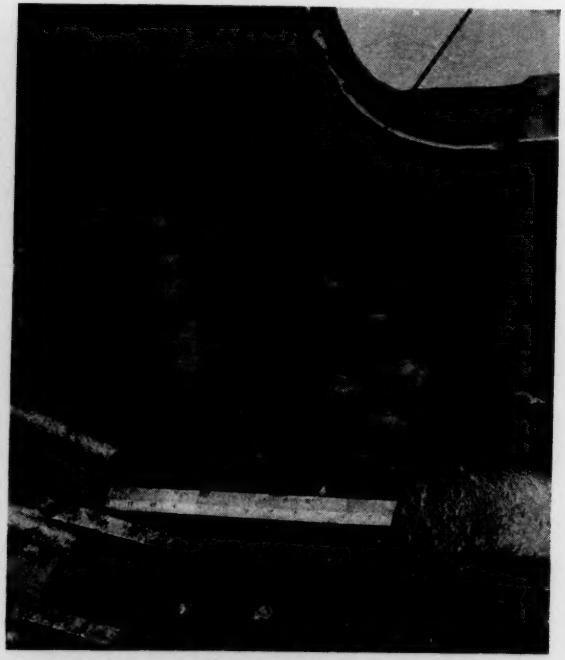

FIGURE 15.—COMPLETED WELD REPAIR. SURFACE EXAMINATION AND X-RAY DISCLOSE NO FURTHER DEFECTS.

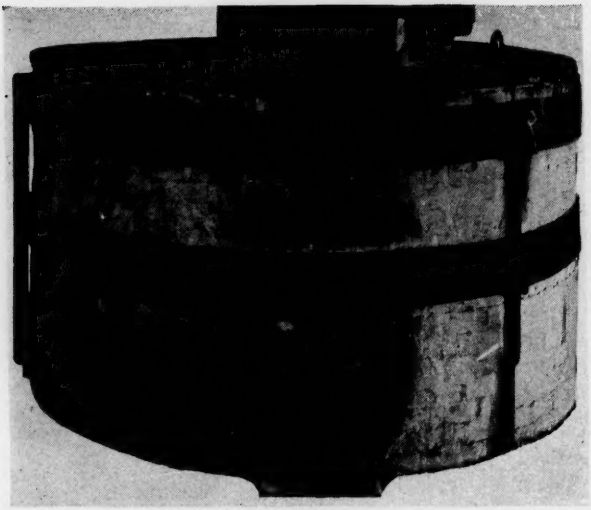

FIGURE 16.—STRESS RELIEVING FURNACE DESIGNED FOR TREATING REPAIRED PORTION OF CARRIAGES.

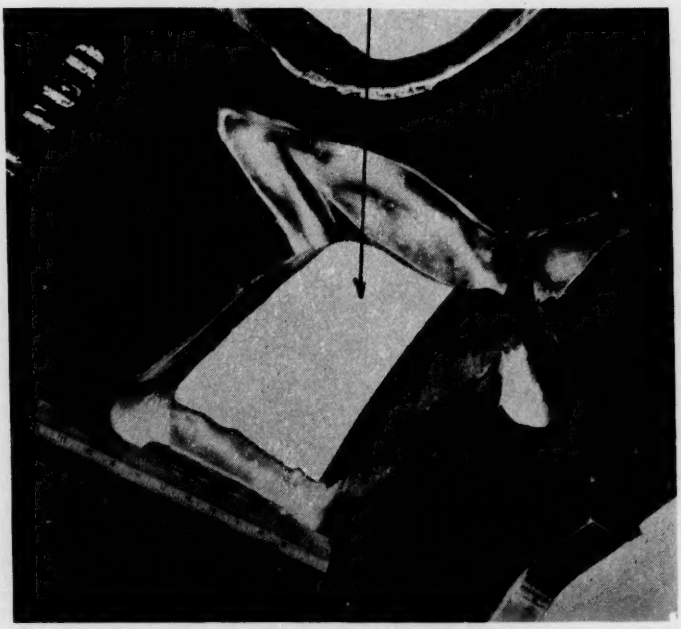

FIGURE 17.—WHERE AN AREA CONTAINS NUMEROUS SMALL TEARS IT IS ADVISABLE TO REMOVE THE ENTIRE SECTION AND REPLACE WITH A PLATE OF SIMILAR SECTION AND PROPERTIES.

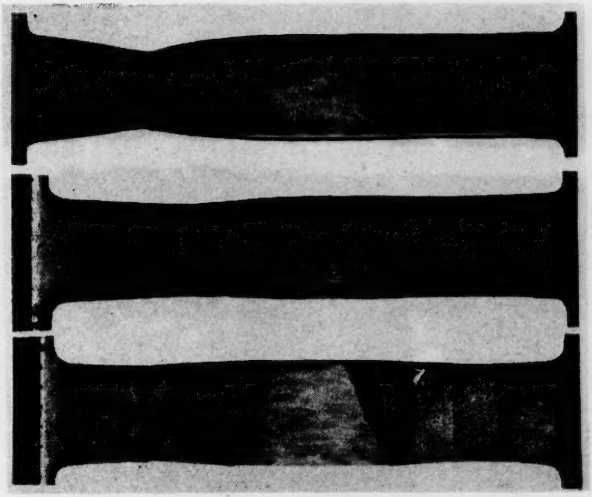

FIGURE 18.—FULL SECTION TENSILE TEST DEMONSTRATING SUPERIOR TENSILE STRENGTH OF WELD METAL. RUPTURE OCCURRED AT 62,000 TO 67,000 POUNDS PER SQUARE INCH DEPENDING UPON THE CASTING STRENGTH.

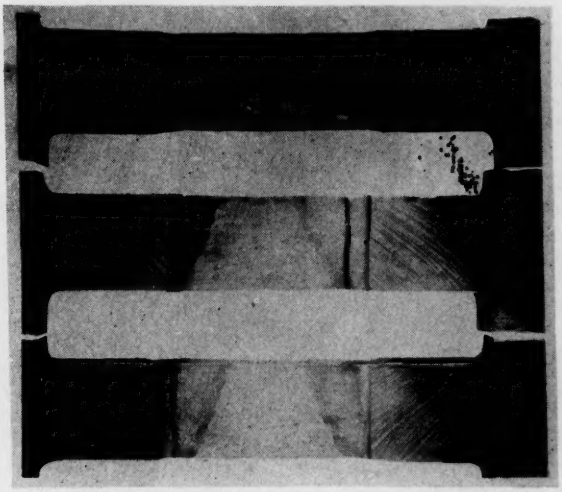

FIGURE 19.—TENSILE SPECIMEN REDUCED IN AREA OF WELD TO CONCENTRATE APPLIED STRESS IN THE DEPOSIT. WELD IS STRONGER THAN CAST SECTION. RUPTURE OCCURRED AT 62,000 TO 70,000 POUNDS PER SQUARE INCH AS DETERMINED BY THE CASTING STRENGTH.

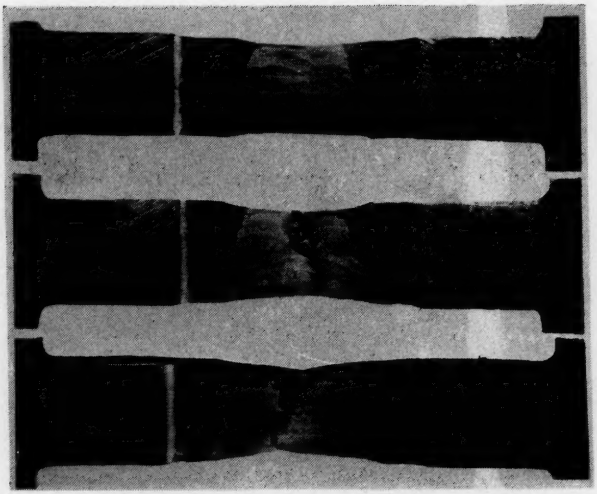

FIGURE 20.—TENSILE SPECIMEN MACHINED SO MINIMUM SECTION IS AT CENTER OF WELD. RUPTURING STRESS OF WELD METAL 70,000 TO 75,000 POUNDS PER SQUARE INCH.

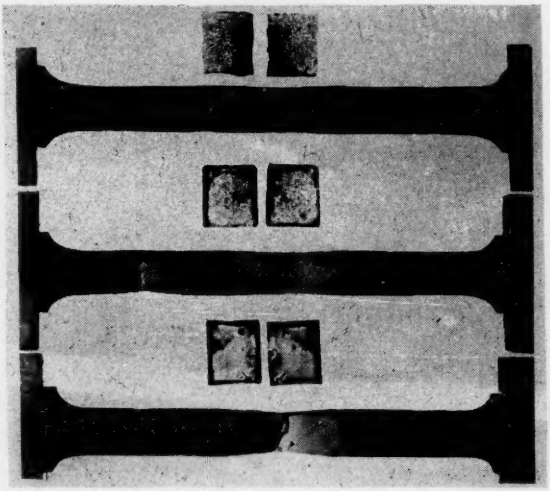

FIGURE 21.—TENSILE IMPACT TESTS SIMULATE FIRING LOADS. THE STRIKING VELOCITY OF LOAD WAS 21.35 FEET PER SECOND. ENERGY OF RUPTURE 1668, 1718 AND 2141 FOOT POUNDS FROM TOP TO BOTTOM, RESPECTIVELY. FRACTURES OCCURRED AT IMPERFECTIONS IN WELD OR CASTING AS SHOWN BY THE RUPTURED SECTION.

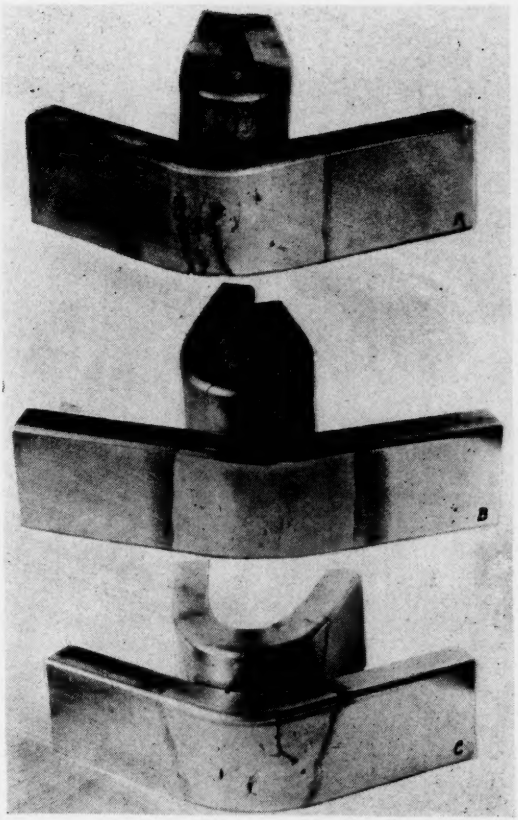

FIGURE 22.—(A) FREE BEND SPECIMEN OF WELDED STEEL CASTING. ELONGATION BEFORE STRESS RELIEVING, 24 PER CENT. THE SAME SECTION STRESS RELIEVED 41 PER CENT ELONGATION. (B) ELONGATION BEFORE STRESS RELIEVING, 9 PER CENT. THE SAME SECTION STRESS RELIEVED 44 PER CENT ELONGATION. (C) ELONGATION BEFORE STRESS RELIEVING, 21 PER CENT. THE SAME SECTION STRESS RELIEVED 40 PER CENT ELONGATION.

61. In cases where warpage beyond the permissible tolerances resulted the parts were ground undersize until the low spots were removed. The undersize pad or bearing races was then electroplated to the required dimensions. This procedure was found necessary only in cases where 20 to 30 pounds of weld metal had been added or where residual stresses were already in the casting.

Defective Areas Replaced.

62. On some carriages where the defective area consisted of numerous small tears, the entire questionable section was removed (as shown in Figure 17) and replaced by welding in a plate having similar physical properties and cross sectional area. After completion, the carriages went into the regular assemblies. The assembled guns were given their proof firing test and all repaired areas again X-rayed. The additional examination was to determine whether any appreciable cracks had occurred between the time welding was finished and stress relieving was completed or during proof firing.

Final X-ray Check.

63. Final X-ray checks of the castings so repaired have disclosed no further defects after being subjected to proof firing tests, in which larger powder charges were used than are employed in regular service firing. Tests demonstrating the desirable physical properties obtained in this repair job are shown by Figures 18, 19, 20, 21 and 22. Weld metal performance in physical tests are usually demonstrated by perfect deposits made under laboratory conditions. The above illustrated tests were taken from shop production rather than selected specimens and demonstrate the relative merits of weld metal and cast metal obtained under average production condition.

FOUNDRY APPLICATIONS OF X-RAY AND WELDING.

64. It is believed that the X-ray can be of material aid in helping the foundryman to control his foundry practice so that sounder castings will be consistently produced. Welding if properly applied can be used effectively to repair extensive defects which may occur in castings from time to time. The soundness of weld repair can be further assured by X-ray examination. Not only can welding be used for repair of defects but complicated castings may be molded in several simplified sections and subsequently assembled by welding them together to form a less expensive and more dependable final product.

COOPERATION OF FOUNDRYMAN AND WELD DESIGNER.

65. The foundryman and the weld designer have in too many cases been rivals since the extensive introduction of weld fabricated rolled steel to replace castings. It appears, however, that cooperation between these two processes will offer advancement in steel construction. Heavy complicated sections of sufficiently uniform thickness may be readily cast. Large light weight sections are rolled, drawn and weld fabricated advantageously. In numerous cases, an assembly, partly of rolled stock and partly of steel castings will be the optimum in the effective use of metal and in fabricating costs.

66. The X-ray and welding are two of the newer tools of the foundryman. Thus far we have had some very successful applications but the field is still naissant. With proper design and carefully controlled procedure, stronger, lighter and more uniformly high quality steel products may be expected.—"American Foundrymen's Association," August, 1935.

BOOK REVIEW.

"TRANSPORTATION BY WATER," BY EMORY R. JOHNSON, GROVER G. HUEBNER, AND ARNOLD K. HENRY, OF THE WHARTON SCHOOL OF FINANCE AND COMMERCE, UNIVERSITY OF PENNSYLVANIA. D. APPLETON–CENTURY COMPANY, $5.00.

The fundamental thesis of this volume is that communication and transportation are very vital factors in our present economic and social organization. It treats of only one phase of this topic, as its title implies, on the general scheme that water transportation is a vast business enterprise. The inland water-ways, intra-coastal shipping, and the Great Lakes are considered as well as foreign ocean commerce.

Various sections deal with the actual physical equipment both afloat and ashore, business organization and methods, insurance, rate making, inter-corporate relationships, and Government regulations.

The section on Government regulation, or rather the public policy toward water commerce, should be of interest to all who are following the destinies of the United States as a maritime nation. This section follows the history of our water commerce in the light of public policy as expressed by act of Congress and Administration from the early beginning down to the present day policy, which as yet has been but partially defined. The book gives a clear insight into the problems which affect or should affect the ultimate policy of our nation.

The early sections could well serve as a text book for a young man about to go into the steamship business. The observations on business organizations would apply with little modification to the majority of American industries. The simplicity of treatment, however, instead of being a fault may have been a well conceived object of the authors.

The volume is profusely illustrated and annotated. Although the authors have attempted not to express definite opinions except in rare cases, the impression is left that they relied heavily on their references. In some instances statements are made as fact, whereas the question is actually one of controversial opinion in which total agreement has not yet been reached.

ASSOCIATION NOTES.

ANNUAL MEETING.

The Annual Meeting of the Society was held at Washington, D. C., on Tuesday, 1 October, 1935. The following were placed in nomination for officers of the Society for 1936:

For President:

Admiral William H. Standley, U.S.N.

For Secretary-Treasurer:

Commander C. S. Gillette, U.S.N.
Commander R. W. Paine, U.S.N.

For Member of Council:

Captain Albert Norris, U.S.N.
Comdr. Penn Carroll, U.S.N.
Comdr. Lybrand P. Smith, U.S.N.
Lt. Comdr. C. A. Bailey, U.S.N.
Captain William McEntee (C.C.), U.S.N.
Comdr. H. E. Saunders (C.C.), U. S. N.
Comdr. G. R. O'Connor, U.S.C.G.
Lt. Comdr. H. A. Curry, U.S.C.G.
Mr. P. N. Israel.
Mr. Roland Whitehurst.
Mr. H. B. Gregory.
Mr. E. F. Sells.

Ballots cast will be counted at the close of business hours on 26 December, 1935.

Decision was made to continue in 1936 the annual banquet of the Society which has proved such an outstanding feature for many years. The event will take place on Friday, 3 April, 1936. Other details will be announced later.

MEMBERSHIP.

The following have joined the Society since the publication of the last previous JOURNAL:

CIVIL.

Zink, John A., 1701 Lakeside Avenue, Baltimore, Md.

NAVAL.

Behrends, Henry J., Chief Machinist, U.S.N.
Broadley, Charles, 229 West 12th St., New York, N. Y.
Dole, Richard W., Lieutenant, U.S.N.
Rooke, William J., Ensign, U.S.N.R., 1212 University Ave., Bronx, New York, N. Y.

ASSOCIATE.

Smith, John S., 40 State St., Wellsville, N. Y.